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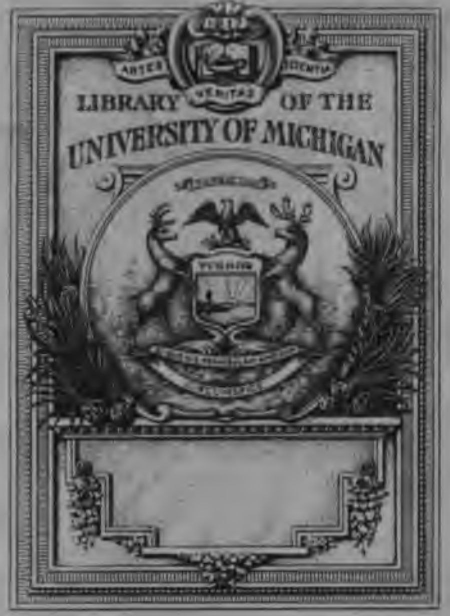

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DIRECTOR

Bulletin No. IV

THE

Physiography and Geology of the Coastal Plain Province of Virginia

BY

William Bullock Clark and Benjamin LeRoy Miller

WITH CHAPTERS ON

The Lower Cretaceous

By Edward W. Berry

AND

The Economic Geology

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CHARLOTTESVILLE
UNIVERSITY OF VIRGINIA
1912

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LYNCHBURG, VA.

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CONTENTS

PAGE

- PREFACE 11
- THE PHYSIOGRAPHY AND GEOLOGY OF THE COASTAL PLAIN PROVINCE OF VIRGINIA. By Wm. Bullock Clark and Benjamin LeRoy Miller 13
  - Introduction 13
  - Geological literature of the Virginia Coastal Plain 19
  - Physiography of the Virginia Coastal Plain 46
    - Introductory 46
    - Submarine division 46
      - General characteristics 46
      - Off-shore beaches and bars 47
      - Coastal lagoons 47
    - Subaerial division 48
      - General characteristics 48
      - Terraces 48
        - Lafayette terrace 49
        - Sunderland terrace 49
        - Wicomico terrace 50
        - Talbot terrace 50
        - Recent terrace 51
      - Sand dunes 52
      - Drainage 52
        - Stream courses 53
        - Tidewater estuaries 54
        - Minor streams 56
        - The Dismal Swamp 56
- GEOLOGY OF THE VIRGINIA COASTAL PLAIN 59
  - Introductory 59
  - Mesozoic 61
    - Cretaceous 61
      - Lower Cretaceous. By Edward W. Berry 61
        - The Potomac group 61
          - The Patuxent formation 63
            - Name 63
            - Stratigraphic relations 63
            - Lithologic character 63
            - Strike, dip, and thickness 64
            - Paleontologic character 65
            - Areal distribution 65
          - The Arundel formation (not recognized in Virginia) 66
          - The Patapsco formation 67
            - Name 67
            - Stratigraphic relations 67
            - Lithologic character 67
            - Strike, dip, and thickness 68
            - Paleontologic character 68
            - Areal distribution 68
          - Detailed sections 69
            - Potomac River 69
            - Rappahannock River 73
            - James River 74
            - Appomattox River 79
            - Section along the Richmond, Fredericksburg and Potomac Railroad 80
      - Upper Cretaceous 87
  - Cenozoic 88
    - Tertiary 88
      - Eocene 88
        - The Pamunkey group 88
          - The Aquia formation 90
            - Name 90
            - Stratigraphic relations 90

PAGE

      - Lithologic character 90
      - Strike, dip, and thickness 91
      - Divisions 91
      - Paleontologic character 91
      - Areal distribution 92
      - Detailed sections 93
        - Potomac River 93
        - Rappahannock River 96
        - Mattaponi River 99
        - Pamunkey River 100
        - Chickahominy River 101
        - James River 101
        - Nottoway River 103
    - The Nanjemoy formation 103
      - Name and areal distribution 103
      - Stratigraphic relations 103
      - Lithologic character 103
      - Strike, dip, and thickness 103
      - Division 104
      - Paleontologic character 104
      - Areal distribution 105
      - Detailed sections 105
        - Potomac River 105
        - Rappahannock River 107
        - Mattaponi River 110
        - Pamunkey River 114
        - James River 115
- Miocene 125
  - The Chesapeake group 125
    - The Calvert formation 126
      - Name 126
      - Stratigraphic relations 126
      - Lithologic character 126
      - Strike, dip, and thickness 127
      - Areal distribution 127
      - Paleontologic character 128
      - Detailed sections 128
        - Potomac River 129
        - Rappahannock River 132
        - Mattaponi River 135
        - Pamunkey and Chickahominy rivers 138
        - James River 138
        - Appomattox River 139
    - The Choptank formation (not recognized in Virginia) 140
    - The St. Mary's formation 141
      - Name 141
      - Stratigraphic relations 141
      - Lithologic character 141
      - Strike, dip, and thickness 142
      - Paleontologic character 142
      - Detailed sections 142
        - Small streams on "Northern Neck" 142
        - Rappahannock River 143
        - Chickahominy and York rivers 145
        - James River 146
        - Blackwater River 149
        - Nottoway River 153
        - Meherrin River 155
    - The Yorktown formation 158
      - Name 158

PAGE
Stratigraphic relations ... 158
Lithologic character ... 158
Strike, dip, and thickness ... 159
Paleontologic character ... 159
Areal distribution ... 159
Detailed sections ... 160
York River ... 160
James River ... 162

Pliocene (?) ... 175
The Lafayette formation ... 176
Name ... 176
Lithologic character ... 176
Strike, dip, and thickness ... 178
Stratigraphic relations ... 178
Paleontologic character ... 178
Areal distribution ... 178
Quaternary ... 179
Pleistocene ... 179
Columbia group ... 179
The Sunderland formation ... 181
Name ... 181
Lithologic character ... 181
Strike, dip, and thickness ... 182
Stratigraphic relations ... 182
Paleontologic character ... 182
Areal distribution ... 183
The Wicomico formation ... 183
Name ... 183
Lithologic character ... 183
Strike, dip, and thickness ... 184
Stratigraphic relations ... 184
Paleontologic character ... 184
Areal distribution ... 185
The Talbot formation ... 185
Name ... 185
Lithologic character ... 185
Strike, dip, and thickness ... 187
Stratigraphic relations ... 188
Paleontologic character ... 188
Areal distribution ... 189
Recent ... 189

CORRELATION OF THE VIRGINIA COASTAL PLAIN ... 191
Cretaceous ... 191
Lower Cretaceous ... 191
The Patuxent formation ... 192
The Patapsco formation ... 194
Upper Cretaceous ... 195
Tertiary ... 199
Eocene ... 200
The Aquia formation ... 200
The Nanjemoy formation ... 201
Miocene ... 202
The Calvert formation ... 203
St. Mary's formation ... 203
The Yorktown formation ... 204
Pliocene ? ... 205
The Lafayette formation ... 205
Quaternary ... 205
Pleistocene ... 206

PAGE
The Sunderland formation 207
The Wicomico formation 207
The Talbot formation 208
Recent 209
GEOLOGICAL HISTORY OF THE VIRGINIA COASTAL PLAIN 210
Pre-Cretaceous history 210
Early Cretaceous history 211
Late Cretaceous history 212
Eocene history 213
Miocene history 213
Pliocene history 215
Pleistocene history 215
Recent history 217
PHYSIOGRAPHIC RECORD 219
Lafayette stage 219
Sunderland stage 220
Wicomico stage 220
Talbot stage 221
Recent stage 222
ECONOMIC PRODUCTS OF THE VIRGINIA COASTAL PLAIN. By Thomas L. Watson 223
Introduction 223
Discussion of individual products 223
Clays 223
Description of clay areas 225
The Alexandria area and vicinity 225
The Fredericksburg area 225
The Wilmont area 226
The Layton area 227
The Milford area 228
The Richmond area 228
The Fort Lee area 231
The Curle's Neck area 232
The Chester area 233
The Bermuda Hundred area 233
The Petersburg area 233
The Broadway area 234
The City Point area 234
The Sturgeon Point area 235
The Oldfield area 235
The Belfield area 236
The Norfolk area and vicinity 236
The Suffolk area 237
Sand and gravel 239
Sand 239
Gravel 241
Diatomaceous earth 243
Greensand marl 247
Calcareous (shell) marl 249
Use in agriculture 250
Use in Portland cement manufacture 252
Mineral paint 257
Iron ore 258
Building stones 258
Peat 259
Underground waters 262
Soils 263

ILLUSTRATIONS

PLATE FACING PAGE

I. **Geological Map of Virginia Coastal Plain** .... in pocket

II. Fig. 1. Bluff at Dutch Gap, James River, looking upstream. Showing Patuxent formation overlain by Pleistocene deposits 63

Fig. 2. Bluff at Dutch Gap, James River, looking downstream. Showing Patuxent formation overlain by Pleistocene deposits 63

III. Fig. 1. Cut on R. F. & P. R. R. near Cockpit Point. Showing sandy beds of Patuxent formation 66

Fig. 2. Cut on R. F. & P. R. R. near Cockpit Point. Showing sandy beds of Patuxent formation 66

IV. Fig. 1. Bluffs above Widewater on Potomac River. Showing Patapsco formation overlain by Pleistocene deposits 68

Fig. 2. Cut on the R. F. & P. R. R. south of Aquia Creek. Showing Patapsco formation overlain by Aquia formation 68

V. Fig. 1. Base of bluff at mouth of Aquia Creek. Showing zones 2 and 4 of Aquia formation 94

Fig. 2. Bluff near mouth of Aquia Creek. Showing blocks of indurated marl derived from zone 9 of Aquia formation, largely composed of shells of *Turritella mortoni* 94

VI. Fig. 1. Bluff at Popes Creek, Maryland, Potomac River. Showing zone 17 of Nanjemoy formation overlain by diatomaceous earth beds of Calvert formation 107

Fig. 2. Bluff at Hopyard, Rappahannock River. Showing calcareous concretions of Aquia formation 107

VII. Fig. 1. Nomini Cliffs, Potomac River. Showing Calvert formation ... 129

Fig. 2. Section 1½ miles below Bowlers Wharf, Rappahannock River. Showing shell marl of St. Mary's formation 129

VIII. Cliff near Yorktown, York River. Showing indurated calcareous beds of the Yorktown formation 161

IX. Fig. 1. Locality at Richmond showing Lafayette formation overlying Calvert formation 177

Fig. 2. Pit at Washington, D. C. Showing Lafayette formation overlying Calvert formation 177

X. Fig. 1. Excavation at Richmond. Showing Lafayette formation overlying Aquia formation 178

Fig. 2. Surface of country at Malvern Hill. Showing Lafayette surface 178

XI. Fig. 1. Excavation at Richmond. Showing gravels and loams of the Sunderland formation 182

Fig. 2. Excavation at Washington, D. C. Showing the Wicomico formation overlying crystalline rocks 182

XII. Fig. 1. Wicomico-Talbot escarpment at Fredericksburg 185

Fig. 2. Talbot Clays at Brick Haven 185

XIII. Fig. 1. Low bluff ½ mile below Bayport Wharf, Rappahannock River. Showing cypress stumps and knees in peat bed of the Talbot formation 186

Fig. 2. Low bluff 1½ miles above Tappahannock, Rappahannock River. Showing cypress stumps and knees in peat bed of the Talbot formation 186

PLATE FACING PAGE

XIV. Fig. 1. View showing large cypress trees in Lake Drummond, Dismal Swamp 190
Fig. 2. Cypress trees and knees of Dismal Swamp 190
XV. Fig. 1. View of sand dunes, Cape Henry 209
Fig. 2. View of sand dunes, Cape Henry 209
XVI. Fig. 1. View of sand dunes, Cape Henry 209
Fig. 2. View of sand dunes, Cape Henry 209
XVII. Fig. 1. General view of Turner's clay pit, Ettricks, near Petersburg ... 213
Fig. 2. View of sandstone blocks in old quarry at Coles Landing, Aquia Creek 213
XVIII. General view of Norfolk Portland Cement Corporation's plant, opposite U. S. Navy Yard, near Norfolk. Storage bin adjoining wharf shown on left; coal house on right; main portion of plant in center. (Courtesy of Wm. H. Stone, Manufacturers Record.) 252
XIX. Fig. 1. View of Miocene (Yorktown) marl beds at Yorktown. The marl is to be used by the Jamestown Portland Cement Corporation for the manufacture of Portland cement 255
Fig. 2. View of Miocene (Yorktown) marl beds along north side of James River, south of Grove Station. The marl is to be used by the Colonial Portland Cement Corporation for the manufacture of Portland cement 255

FIGURE PAGE
1. Diagrammatic representation of the east bank of Dutch Gap Canal 77

LETTER OF TRANSMITTAL

VIRGINIA GEOLOGICAL SURVEY,
UNIVERSITY OF VIRGINIA,
CHARLOTTESVILLE, January 20, 1912.

To His Excellency, Hon. Wm. Hodges Mann, Governor of Virginia, and Chairman of the State Geological Commission:

Sir:—I have the honor to transmit herewith for publication, as Bulletin No. IV of the Virginia Geological Survey Series of Reports, a report on "The Physiography and Geology of the Coastal Plain Province of Virginia," by Professors Wm. Bullock Clark and Benjamin LeRoy Miller, with a chapter on the "Economic Products," by Thomas Leonard Watson, State Geologist.

The investigations embodied in this report have been conducted by the Virginia Geological Survey in coöperation with the U. S. Geological Survey, with Dr. T. Wayland Vaughan of the U. S. Geological Survey as supervising geologist in charge of the work.

Respectfully submitted,

THOMAS L. WATSON,
Director.

PREFACE

This report contains a discussion of the physiography and geology of the Coastal Plain province of Virginia. All of the formations here represented are found in adjacent states either to the north or to the south. The Virginia region is classic ground for the student of Atlantic Coast Tertiary geology, while the Cretaceous deposits are also well known. There are few portions of the Coastal Plain that have received more attention, although the greater portion of the work done in Virginia dates from an early period when individual sections were studied and their fossil contents collected and discussed. Little was done at that time toward delimiting either the formational units or their areal distribution, while the broader physiographic problems were quite untouched. The present investigation has endeavored to cover these larger problems. The work has been carried on in conjunction with similar studies in Maryland and North Carolina.

The first chapter, entitled *Physiography of the Virginia Coastal Plain*, deals with the surface features of the district, which consist mainly of a series of dissected terraces formed during late Tertiary and Quarternary times. The similarity of this region to the adjoining areas in Maryland and North Carolina is clearly shown.

The second chapter, entitled *Geology of the Virginia Coastal Plain*, comprises an exhaustive study of the character and distribution of the formations of eastern Virginia. This investigation began nearly twenty years ago, when the senior author of this report started his study of the geology and paleontology of the regions bordering the main drainage lines of the district. Excursions covering longer or shorter intervals were made yearly from that time forward. In later years the junior author of this report has spent much time in the field mapping the limits of the several formations, and in making still further paleontological collections. As the result of the prolonged investigation to which the district has been subjected, the authors of this report are able to present much in the way of detailed results.

The authors have been materially aided in the study of the Lower Cretaceous formations by Mr. E. W. Berry, of the Johns Hopkins University, who has spent much time in the field studying the detailed stratigraphy of these formations, and in collecting the fossil plants, a thorough revision at the same time being made of the specific determinations of his predecessors. Mr. Berry is the author of the section on the Lower Cretaceous. Dr. M. W. Twitchell, of South Carolina University, did much valuable work as an assistant in the study of the Miocene formations in several of the southern counties of the State. Miss Julia A. Gardner, of the Johns Hopkins University, has devoted much of her time for the past two years to a study of the Miocene faunas, more especially to the mollusca, which are very extensively represented, and which furnish the best criteria for the recognition of the Miocene formations. The senior author of this report has also been engaged in a study of the Eocene fauna, to which he has long given much attention.

These studies, together with others which have been undertaken by specialists in other groups, will afford the materials for a series of systematic reports on the geology and paleontology of the Coastal Plain of Virginia, which will follow the present contribution as rapidly as possible.

The third chapter deals with the *Geological History of the Virginia Coastal Plain.* The various geological events which have transpired in Virginia during the building up of the Coastal Plain series of deposits are discussed, and the relationships of these events to the history of the entire Coastal Plain is considered.

The fourth chapter deals with the *Correlation of the Virginia Coastal Plain* formations, comparisons being instituted with the known horizons of adjacent states, as well as the hitherto recognized series of the Gulf, and even in some instances with European deposits.

The authors desire to express their obligations to Messrs. E. W. Berry and L. W. Stephenson, who have been carrying on an exhaustive field investigation of the Coastal Plain formations of the South Atlantic and Gulf states under the direction of Dr. T. Wayland Vaughan. This work has resulted in clearing up many disputed points, but the final results are not yet available for use in the present report.

The fifth chapter, entitled *Economic Products of the Virginia Coastal Plain,* by the State Geologist, embraces a discussion of the more important products of commercial value found in the various formations of eastern Virginia. Many undeveloped resources are found in this district, and attention is briefly directed to them in this connection.

Thanks are particularly due to the U. S. Geological Survey in coöperation with whom this investigation has been conducted. This report is one of a series being prepared by the Federal and State Surveys on the geology and water resources of the Coastal Plain under the supervision of a joint committee consisting of members of the U. S. Geological Survey and the State Geologists of the states involved, of which Dr. Wm. Bullock Clark, of the Johns Hopkins University, is chairman. Dr. Clark has under his direct charge the study of the district extending from North Carolina to New England. Dr. T. Wayland Vaughan, of the U. S. Geological Survey, is supervising geologist in charge of the entire work.

THOMAS L. WATSON,
Director.

THE PHYSIOGRAPHY AND GEOLOGY OF THE COASTAL PLAIN PROVINCE OF VIRGINIA

BY WM. BULLOCK CLARK AND BENJAMIN LE ROY MILLER.

INTRODUCTION

Geographers have long recognized three physiographic regions within the Middle Atlantic slope. They are known, beginning on the west, as the Appalachian Mountains, the Piedmont Plateau, and the Coastal Plain. While each one of these regions has its own peculiar characteristics, it nevertheless passes into that adjoining by insensible gradations.

The Appalachian Mountain region is composed of flat-topped ridges separated by deep, steep-sided and flat-bottomed valleys which have been carved from folded beds of limestone, sandstone, and shale of Paleozoic age.

The Piedmont Plateau exhibits a rolling surface which, along its eastern margin, is dissected by deep river gorges. It consists of metamorphosed sediments of pre-Cambrian and early Paleozoic age, into which great masses of igneous rocks have been injected. Overlying these ancient rocks in certain regions are Triassic beds which are in turn cut by eruptive rocks. The structure of the Piedmont Plateau is exceedingly complicated and has only been thoroughly worked out in a few regions.

The Coastal Plain also has a rolling topography along its western margin, where it blends with the Piedmont Plateau, but throughout most of its eastern half it is flat and featureless. The deposits of the Coastal Plain are much younger than those of the other two regions and consist of unconsolidated sediments of late Mesozoic and Cenozoic age which have suffered few disturbances since their deposition.

The boundary of the Atlantic Coastal Plain to the eastward is marked by the well-defined scarp of the continental shelf which, off the Virginia coast, lies from 30 to 50 miles to the eastward of the present shore-line. It forms an escarpment along the western portion of the true oceanic basin with a height of from 5,000 to 10,000 feet or more. By common practice the 100-fathom line is regarded as the boundary of the continental shelf although the depth of the water is often nearly twice that amount where the abrupt change occurs. The descent of the slope to the greater ocean depths is rapid; at Cape Hatteras there is an increase in depth of 9,000 feet in 13 miles, a grade as steep as that often found along the flanks of the greater mountain systems. In striking contrast to this declivity is the comparatively flat ocean bed stretching away to the east, with but slight differences in elevation. Looked at from the base the escarpment would have the appearance along its crest of a high mountain range with a very even sky line. Here and there notches would be seen, produced by the streams which once flowed across the continental shelf, but there would be no peaks or serrated ridges.

The western limit of the Atlantic Coastal Plain is defined by a belt of crystalline rocks, consisting of greatly metamorphosed igneous and sedimentary materials, ranging in age from the pre-Cambrian to the Silurian period. These rocks form the eastern portion of the Plateau province. Most of the larger streams and many of the smaller ones, as they cross the western margin of the Coastal Plain, are characterized by falls or rapids and always show a marked decrease in the velocity of their currents, the name "fall-line" being given to this boundary on that account. The position of the "fall-line" near the head of navigation or near the source of water-power has been one of the very important factors in determining the location of many of the towns and cities of the Atlantic coast; Newark, Trenton, Philadelphia, Wilmington, Baltimore, Washington, Fredericksburg, Richmond, Petersburg, Raleigh, Camden, Columbia, Augusta, Macon, and Columbus being located on this boundary. A line drawn through these places would approximately separate the Coastal Plain from the Piedmont Plateau. Along the eastern margin of the Piedmont district outliers of the Coastal Plain are frequent, while along the valleys of the larger streams the crystalline rocks can at times be followed for a mile or more into the body of the Coastal Plain sediments where the mantle of the latter has been cut through.

The Atlantic Coastal Plain is divided into two parts by the present shore-line, a submerged or *submarine* portion known as the continental shelf, or continental platform, and an emerged or *subaerial* portion commonly called the Coastal Plain. In some places the division line is marked by a sea cliff of moderate height, but usually the two grade into each other with scarcely a perceptible change, and the only mark of separation is the shore-line. The areas of the respective portions have changed frequently during past geologic time by the shifting of the shore-line eastward or westward, due to local and general depressions or elevations of greater or less extent, and even at the present time such changes are in progress. Old river valleys, the continuations of channels of existing streams, have been traced entirely across the continental shelf at the margin of which they have cut deep gorges. The Hudson River channel is particularly well marked and has been shown to extend almost uninterruptedly to the edge of the shelf over 100 miles to the east of its present mouth. The same is true of Chesapeake Bay. This sheet of water so broad and deep to-day and affording the great highway of commerce for Virginia's export trade as well as the unparalleled local transportation facilities for the tidewater country, is the submerged lower valley of the old Susquehanna River which flowed across Maryland and Virginia and found its way seaward past the Capes, its channel continuing across the sea floor of the submarine portion of the Coastal Plain.

The combined width of the submarine and subaerial portions of the Coastal Plain province is quite uniform along the entire eastern border of the continent, being approximately 250 miles. In Florida and Georgia the subaerial portion is over 150 miles wide, the eastern submerged portion being much narrower, and along the southeastern shore of the peninsula of Florida it is almost wanting. Northward the submerged portion gradually increases in width, while the subaerial portion becomes narrower. Except in the region of Cape Hatteras, where the submarine belt becomes narrower with a corresponding increase in width of the subaerial belt, this gradual change continues as far as the southern part of Massachusetts, beyond which the subaerial portion disappears altogether through the submergence of the entire Coastal Plain province. Off Newfoundland the continual shelf is about 300 miles in width.

The surface of the Coastal Plain has a gentle slope from the "fall-line" to the east, gradually declining eastward from five feet to the mile to one foot or even less, except in the vicinity of the Piedmont Plateau, where the slope is occasionally as great as 10 to 15 feet to the mile and in a few instances even more rapid. The submerged portion which slopes even less rapidly eastward is monotonously flat as desposition has destroyed most of the irregularities produced by erosion when it formed a part of the land area. The slight elevation of the subaerial portion which seldom reaches 400 feet, and is for the most part less than half that amount, has prevented the streams from cutting valleys of great depth. The country, however, in the vicinity of the larger streams shows considerable relief, although the variations in altitude are only a few hundred feet. Throughout a great portion of the area this relief is very inconsiderable, the streams flowing in open valleys at only a slightly lower level than the broad flat divides.

The land portion, or the subaerial division, of the Coastal Plain province is marked by the presence of many bays and estuaries, representing submerged valleys of streams carved out during the time when the region stood at a higher level than at present. Chesapeake Bay, which is the old valley of the Susquehanna River, and Delaware Bay, which is the extended valley of the Delaware River, together with such tributary streams as the Patuxent, Potomac, York, and James rivers are examples of such bays and estuaries, of which there are many others of less importance. The streams which have their sources in regions to the westward are almost invariably turned in a direction roughly parallel to the strike of the formations as they pass out into the Coastal Plain. This is well shown in the case of the Potomac and James rivers which at Washington and Richmond suddenly change their courses and flow in an almost southerly direction for several miles. With this exception the structure of the formations and the character of the materials have had little effect upon stream development except locally.

The materials of which the Coastal Plain is composed consist of boulders, pebbles, sand, clay, and marl, mostly loose or locally indurated. In age the formations range from Lower Cretaceous to Recent. Since the time when the oldest formations of the province were formed there have been many periods of deposition alternating with erosion intervals. The sea, however, advanced and retreated differently in various parts of the region, so that at the present time few of the formations can be traced by outcropping beds throughout the entire area. Different conditions thus prevailed and great variability in the deposits has been produced during each period.

The Virginia Coastal Plain occupies the eastern portion of the State and has an area of somewhat more than 14,000 square miles, of which about 10,000 square miles belong to the subaerial division or Coastal Plain proper, and about 4,000 square miles to the submarine division. In the former are also included the estuarine waters of the lower Chesapeake Bay with the tributaries of the Rappahannock, York, James, and other rivers, which together have an area of about 3,000 square miles. The Coastal Plain proper forms about one-fourth of the entire area of the State. On account of the tidal bays and estuaries which traverse it in all directions it has received the name of "tide-water Virginia" and its nearly 2,000 miles of shore-line is bordered at almost all points by navigable waters.

To the north and south the Coastal Plain of Virginia is continuous with the Coastal Plain regions of Maryland and North Carolina; to the east the region is bounded by the basin of the Atlantic Ocean; and to the west a much more irregular and less easily determined line separates it from the Piedmont Plateau. The difficulty in drawing the westward limiting line is due to the relations existing between the formations of the two regions, the

Coastal Plain deposits resting upon an uneven eastward-sloping floor of Piedmont Plateau crystalline rocks. In the depressions of this floor much thicker deposits accumulated than in other places. Everywhere also the deposits thin out toward the west and, since the deposition of the beds, erosion has in many places destroyed the continuity of the mantle of unconsolidated materials. Thus outliers of Coastal Plain sediments, separated from the continuous cover by miles of intervening crystalline rocks, are common.

The deposits of the Lafayette formation particularly are frequently found overlying the Piedmont crystallines as isolated patches many miles beyond the limits of the great mass of Coastal Plain sediments. A few miles to the west of Falls Church in Fairfax County is a striking instance of such an outlier of Coastal Plain deposits, covering several square miles, and separated from the continuous mantle farther east by a distance of quite five miles. A similar outlier of considerable extent occurs near the small village of Midlothian in the northwestern part of Chesterfield County. Several miles of crystalline rocks intervene between it and the main body of the Coastal Plain deposits. Many such Coastal Plain outliers of large and small extent occur throughout the eastern part of the Piedmont Plateau. They furnish evidence of a former much more extensive Coastal Plain whose marginal deposits have been largely removed by erosion, leaving only small remnants over the divides or in places where, on account of depressions, the deposits were unusually thick. The present streams which have cut through the thin marginal strata have exposed the underlying crystalline rocks at times many miles to the east of the points where they are still concealed from view on the uplands of the stream divides. Along the larger streams these crystalline rocks disappear near the level of tide. Even disregarding the outliers mentioned above, the boundary line between the Piedmont Plateau and the Coastal Plain in Virginia is a very irregular line running in a general north and south direction but bending eastward in the valleys of all the eastward-flowing streams and westward over the intervening divides.

Along the Potomac River the crystalline rocks finally disappear at Washington; along the Rappahannock they are not seen to the east of Fredericksburg; along the James River they disappear at Richmond, but because of great irregularity in the crystalline floor or on account of post-Tertiary disturbance, they again appear in one place a short distance above Dutch Gap canal; while along the Meherrin River the crystalline rocks disappear below water level a short distance below Emporia. Over the divides the continuous cover of Coastal Plain sediments extends from three to ten miles farther to the west. Geographically, the westward limiting line of the Coastal Plain of Virginia passes through the eastern part of Fairfax, Prince William, Stafford and Spottsylvania counties, the extreme western part of Caroline County, the central part of Hanover, Henrico, and Chesterfield counties, the eastern part of Dinwiddie County, the western part of Sussex County, and the eastern part of Greenesville County.

GEOLOGICAL LITERATURE OF THE VIRGINIA COASTAL PLAIN

1783

Lincoln, Gen. Benj. An account of several strata of earth and shells on the banks of York River, in Virginia.

Mem. Amer. Acad. Arts and Sci., vol. i, pt. ii, pp. 372-373, 1783.

This is the earliest known reference to the geology of the Coastal Plain of Virginia and for that reason the article is quoted in its entirety. "That this earth, since its formation, has met with great changes, and that the shores, now covered with the tallest cedars and most luxuriant plants, were once washed by the ocean, none can deny. The land between *James-river* in *Virginia,* is very level; its surface being about forty feet above high-water mark. It appears to have arrived to its present height at different periods, far distant each from the other, by means of the ocean: for, near *York-town,* where the banks are perpendicular, you can first see a stratum of earth, about five feet high, intermixed with small shells, which has the appearance of a mixture of clay and sand. On that lies, horizontally, a stratum of white shells, the cockle, the clam, and others, an inch or two thick; then a body of earth, similar to the first mentioned, eighteen inches thick; and on that lies another thin body of small shells, then a third body of earth, about the same thickness as the last; and on that lies another body of white shells, of various kinds, about three feet thick, with very little sand, or earth, mixed with them. On these lies a body of oyster-shells, about six feet thick; then a body of earth to the surface. The oyster-shells are so united by a very strong cement, that they fall only when undermined, and then in large bodies, from one to twenty tons weight. They have the appearance of large rocks on the shores and are wasted by the frequent washing of the sea. All these different strata seem to be perfectly horizontal.

"After riding about seven miles from *York-town,* near the center between the two rivers, I discovered, at a place from which a large body of earth had been removed to a mill-dam, nearly the same appearance as in the bank first mentioned.

"What they call their stone, with which they built in *York-town* is nothing more than shells, united by a strong cement, which seems to be petrified in a degree, but is apparently affected by the weather."

1799

Latrobe, B. Henry. Memoir on the Sand-hills of Cape Henry in Virginia.

Trans. Amer. Phil. Soc., vol. iv, pp. 439-444, Phila., 1799.

The aqueous origin of the Coastal Plain is advocated in the following statements: "That the whole of this extensive country, from the falls of the coast, is factitious, and of Neptunian origin, appears far from being hypothetical; and the fossil teeth and bones (shark's teeth, fish vertebræ, etc.) which accompany this memoir, and which with many hundred more, were dug out of a well at Richmond, from the depth of 71 feet, prove that the deposition of the superstrata is not of a date sufficiently removed to have destroyed the soft and almost cartilaginous part of the joints, or to have injured the enamel of the teeth. The Neptunian theory of geogeny, has now very generally taken the place of the old volcanic system, and, as far as conjecture and hypothesis can forward science, it is certainly more generally applicable."

A very good account of the Cape Henry sand hills is given. From the description it is evident that the sand dunes have changed very little during the past hundred years, although Latrobe found that the growth and advance of the sand dunes had been comparatively rapid for some time previous to his observations.

1809

LATROBE, B. H. An account of the Freestone quarries on the Potomac and Rappahannock rivers. Read Feb. 10, 1807.

Trans. Amer. Phil. Soc., vol. vi, pp. 283-293. Phila., 1809.

The quarries of Potomac sandstone near the mouth of Aquia Creek and on the Rappahannock River near Fredericksburg are described. Latrobe likened the deposits to the sand dunes at Cape Henry and suggested a common origin for both deposits. He supposed that at one time the Potomac sands were beach dunes which had been heaped up by the wind.

MACLURE, WILLIAM. Observations on the Geology of the United States, explanatory of a Geological Map. Read Jan. 20, 1809.

Trans. Amer. Phil. Soc., vol. vi, pp. 411-428, map. Phila., 1809. Republished with additions in 1817 and 1818.

A general account of the geology of the United States in which the limits of the Atlantic Coastal Plain are roughly defined and the Coastal Plain deposits briefly described under the title of the "Alluvial Formation."

1818

MITCHELL, SAMUEL L. Observations on the Geology of North America, illustrated by the description of various organic remains found in that part of the world.

Cuvier's Essay on the Theory of the Earth, pp. 319-424, 3 pls., New York, 1818.

Mention is made of vertebrate bones and teeth found in Richmond of the ribs and vertebræ of a whale found near Williamsburg in 1802, and the remains of a mammoth found in 1811 on the York River about 6 miles east of Williamsburg. The Richmond fossils were probably from the Aquia, the Williamsburg ones from the St. Mary's or Yorktown, and the bones of the mammoth from the Talbot.

1824

FINCH, JOHN. Geological Essay on the Tertiary Formations in America. Read before the Acad. of Nat. Sci. at Phila., July 15, 1823.

Amer. Jour. Sci., vol. vii, pp. 31-43, New Haven, 1824.

In this article the writer objects to the term "Alluvial" being used to include all the Coastal Plain formations and advocates the separation of the Tertiary formations from the alluvial beds. He correlates the fossiliferous beds at Richmond (Eocene?) and Williamsburg (Miocene) with the London Clay.

1826

PIERCE, JAMES. Practical remarks on the shell marl region of the eastern parts of Virginia and Maryland, and upon the bituminous coal formation in Virginia and the contiguous region.

Amer. Jour. Sci., vol. ii, pp. 54-59, New Haven, 1826.

The wide distribution of rich shell marl "of marine origin" throughout the Coastal Plain of Virginia and Maryland is mentioned and the writer advocates the use of the material as a fertilizer on exhausted soils. Cases are cited where the soil was rendered much more productive by the addition of a thin layer of the shell marl.

1832

Conrad, T. A. Fossil Shells of the Tertiary Formations of America. Vol. i, Nos. 1-3, 56 pp., 20 pls., Phila., 1832-35. Republished by G. D. Harris, Washington, 1893.

In this work molluscan fossils are described from Yorktown, Smithfield, and Suffolk. In the first part (No. 1) of the work the deposits in eastern Virginia are designated as the Upper Marine or the Upper Tertiary while in the last part (No. 3) the same deposits are called Medial Tertiary or Older Pliocene. In this latter part the Eocene is mentioned as occurring in Virginia "forming the western boundary of the Pliocene."

1833

Conrad, T. A. On some new Fossil and Recent Shells of the United States.

Amer. Jour. Sci., vol. xxiii, pp. 339-346, 1835.

Several new species of fossils from Yorktown, Suffolk, and Smithfield are described from the "upper marine" (Miocene) formation.

1834-5

Conrad, T. A. Observations on the Tertiary and more Recent Formations of a Portion of the Southern states.

Jour. Acad. Nat. Sci., Phila., vol. vii, pp. 116-129, 1834.

The occurrence of the Eocene and "Pliocene" (Miocene) is noted along the James River and the statement is made that the "Pliocene" deposits there contain *Ostrea compressirostra.*

Rogers, Wm. B. Some observations on the Tertiary Marl of Lower Virginia. The Farmers Register, 1834-5. Reprint of Report on the Geology of the Virginias, pp. 1-20, New York, 1884.

In a letter to the editor of the *Farmer's Register* dated June 26, 1834, Professor Rogers reports the presence of greensand near Williamsburg, Kings Mill, and at Bellefield, which he was hopeful would furnish as good greensand for fertilizing purposes as that of New Jersey. In the *Farmer's Register* for 1835 the value of the shell marls near Williamsburg and Yorktown for fertilizing purposes is discussed. The writer follows Conrad in placing the Yorktown, James River, Smithfield, and Suffolk beds in the Middle Tertiary. He also reports the presence of the Lower Tertiary or Eocene in Virginia along the Potomac, Rappahannock, Pamunkey, and James rivers and described its lithologic characters. *Cardita planicosta, Ostrea sellæformis,* and *Fusus longævis* are said to occur in great numbers in all localities examined and the entire fauna shows marked relationships to the Eocene of Alabama, Paris and London. The greensand and gypsum of the Eocene deposits are both said to be valuable for fertilizing purposes.

1835

CLEMSON, THOMAS G. Notice of a Geological Examination of the Country between Fredericksburg and Winchester in Virginia, including the Gold Region.

Trans. Geol. Soc. of Penn., vol. i, pp. 298-313, Phila., 1835.

The lithological characters of the Potomac deposits in the region of Fredericksburg are described.

CONRAD, T. A. Observations on a Portion of the Atlantic Tertiary Region.

Trans. Geol. Soc. of Penn., vol. i, pp. 335-341, pl. 13, Phila., 1835.

The contact between the Eocene and "older Pliocene" (Miocene) is noted as exhibited on the James River near City Point and again at Coggin Point. A species of coral from the Miocene of Virginia is described and figured.

——— Observations on the Tertiary Strata of the Atlantic Coast.

Amer. Jour. Sci., vol. xxviii, pp. 104-111, 280-282, 1835.

The beds at Yorktown, on the James River near "Smithfall" (Smithfield ?) and Suffolk, are referred to the Medial Pliocene, which formation is characterized by the presence of 30 per cent. of living species in the fossil fauna. The beds now referred to the Calvert, Choptank, and St. Mary's formations are termed "Older Pliocene" and are characterized by numerous specimens of *Perna maxillata* and a few living species. The Miocene is said to be "probably wanting."

TAYLOR, RICHARD C. Notice of Certain Fossil Acotyledonous Plants in the Secondary strata of Fredericksburg.

Trans. Geol. Soc. of Penn., vol. i, pp. 320-325, pl. 19, Phila., 1835.

Six plants from the Potomac deposits are described and figured in this article.

1836

ROGERS, WILLIAM B. Report of the Geological Reconnaissance of the State of Virginia.

144 pp., 1 map, Phila., 1836.

Reprint of Reports on the Geology of the Virginias, pp. 21-122, New York, 1884.

The geographic distribution, the stratigraphic relations, and lithologic characters, the conditions of deposition, and the economic products of the Miocene and Eocene strata are all discussed. The superficial deposits of sands, gravels, indurated ferruginous sandstones, and ochreous clays are described from the Middle Tertiary (Miocene) district but are not separated from the Miocene strata.

1837

——— Report of the Progress of the Geological Survey of the State of Virginia for the year 1836.

22 pp. Richmond, 1837. Another edition, 14 pp. 4°, Richmond, 1837. Reprint of Reports on the Geology of the Virginias, pp. 122-145, New York, 1884.

The geographic distribution and lithologic characters of the Eocene and Miocene deposits occurring on the peninsula lying between the Potomac and Rappahannock rivers are described and the economic value of the greensand and shell marl deposits discussed.

Rogers, W. B. and H. D. Contributions to the Geology of the Tertiary Formations of Virginia. Read May 5, 1835.

Trans. Amer. Phil. Soc., vol. v (n. s.), 1837, pp. 319-341.

Reprinted in part in Geology of the Virginias, pp. 661-668, New York, 1884.

The character of the country and the geology of Elizabeth City, Warwick, York, and James City counties with parts of New Kent and Charles City counties are discussed at considerable length. The sections at Kings Mill and Yorktown are described in particular. The Miocene age is determined by the presence of only 19 per cent. of recent species found in the deposit at Kings Mill, where 74 species have been described. New species of Miocene fossils from Williamsburg and Prince George County are described.

The Eocene deposits on the James River together with some new species of Eocene fossils are briefly described.

The superficial deposits resting unconformably upon the Miocene are mentioned, but in the absence of fossils no conclusion is reached regarding their age.

1838

Conrad, T. A. Fossils of the Medial Tertiary of the United States.

No. 1, 32 pp., 17 pls., Phila., 1838. Republished with an introduction by W. H. Dall, Phila., 1893.

The geographical limits of the formation, the lithologic characters of the strata, and the conditions of deposition are all described. The deposits are correlated with the Crag of England. Fossils from Yorktown, Smithfield, Suffolk, City Point, and Williamsburg are described and figured.

Rogers, Wm. B. Report of the Progress of the Geological Survey of the State of Virginia for the year 1837.

24 pp., 4°, Richmond, 1838. Reprint of Reports on Geology of the Virginias, pp. 145-188, New York, 1884.

The report contains partial analyses, giving the carbonate of lime content only, of over 150 specimens of Miocene and Eocene marls from the Coastal Plain counties. The non-occurrence in Virginia of "secondary greensand (Cretaceous) beds, similar to those of New Jersey" between the Eocene and the "coarse conglomerates, sandstones, and clays which overlie the primary rocks" is expressly stated.

1839

Conrad, T. A. New Species of Fossil Shells.

1 p., Phila., 1839. Republished by W. H. Dall, Phila., 1893.

New fossils from Urbanna, Yorktown and Smithfield are described.

Rogers, W. B. and H. D. Contributions to the Geology of the Tertiary Formations of Virginia. Second series. (Read March 1, 1839.)

Trans. Amer. Phil. Soc., vol. vi (n. s.), pp. 347-377, pls. 25-30, 1839. Reprinted in part in Geology of the Virginias, pp. 669-673, New York, 1884.

The topography and geology of the Northern Neck embracing the counties of Lancaster, Northumberland, Richmond, Westmoreland, and King George, and the eastern part of Stafford County are discussed and many outcrops of Miocene and Eocene strata described. A few new species of fossils from the Miocene and Eocene are described and figured.

——— Contributions to the Geology of the Tertiary Formations of Virginia. Second series.

Proc. Amer. Phil. Soc., vol. i, pp. 88-90, 1839.

Abstr. Amer. Jour. Sci., vol. xxxviii, pp. 183-184, 1840.

The geology of the peninsula embraced between the Potomac and Rappahannock rivers from Chesapeake Bay to the head of tidewater is described. The stratigraphy, lithology, and paleontology of the Eocene and Miocene strata are briefly described.

1840

CONRAD, T. A. Fossils of the Medial Tertiary of the United States.

No. 2, pp. 33-56, pls. 18-29, Phila., 1840. Republished by W. H. Dall. Phila., 1893.

Miocene fossils from City Point, Smithfield, Yorktown, Suffolk, Urbanna, and Lancaster counties are described and figured.

LEA, HENRY C. Description of some new Fossil shells from the Tertiary of Petersburg, Va.

Trans. Amer. Phil. Soc., vol. ix, 1840, (n. s.), pp. 229-274, pls. 34-42.

One hundred and five new species are described and figured, making in all 178 species from the Miocene strata at Petersburg. Of these only nine can be identified with existing forms.

ROGERS, WM. B. Report of the Progress of the Geological Survey of the State of Virginia for the year 1839.

161 pp., 2 pls., Richmond, 1840. Reprint of Reports of the Geology of the Virginias, pp. 245-410.

The region lying south of the James River is discussed in great detail and the physiography, stratigraphy, and lithology of the area are very accurately described. The structure of the Coastal Plain is discussed more fully than in any of the earlier reports. The escarpment lying to the west of the Dismal Swamp is said to represent an old sea cliff which separates the low-lying region of the Norfolk area from the higher-lying flat plain to the west.

1841

HODGE, JAMES T. Observations on the Secondary and Tertiary Formations of the Southern Atlantic States with an appendix describing new shells by T. A. Conrad.

Abst. Amer. Jour. Sci., vol. xli, pp. 182-183, 332-448, pl. ii, 1841.

Trans. Assoc. Amer. Geol. and Nat., pp. 34, 35, 94-III, pl. v, Boston, 1843.

The Eocene marl exposures on the Rappahannock and Pamunkey rivers are described, and the use of the marl as a fertilizer is highly recommended.

Rogers, Wm. B. Report of the Progress of the Geological Survey of the State of Virginia for the year 1840.

132 pp., Richmond, 1841. Reprint of Reports on the Geology of the Virginias. pp. 411-535, New York, 1884.

The report contains detailed descriptions of the Miocene, Eocene, and Potomac (called Upper Secondary) strata of the Northern Neck. The stratigraphic relations and lithologic characters are very accurately described, while lists of the most abundant fossils are given. The Tertiary strata exposed in the valley of Shockoe Creek, Richmond, are also described.

1842

Conrad, T. A. Observations on a Portion of the Atlantic Tertiary Region, with a Description of New Species of Organic Remains.

Proc. Nat. Inst. Promotion Sci., vol. i, pp. 171-194, pls. i-ii, Washington. 1842.

The geographic limits and stratigraphic relations of the Eocene and Miocene in Virginia are given. The presence of *Ostrea sellæformis* is employed to separate the Eocene from the Miocene.

Lyell, Charles. On the Tertiary Formations and their connection with the Chalk in Virginia and other Parts of the United States.

Proc. Geol. Soc. London, vol. iii, pp. 735-742, 1842.

Brief mention is made of the Eocene and Miocene strata of Virginia and their contained fossils.

Tuomey, M. Discovery of a chambered Univalve Fossil in the Eocene Tertiary of James River, Virginia.

Amer. Jour. Sci., vol. xliii, 1842, p. 187.

This article contains some conclusions of the author regarding the stratigraphy of the Eocene, based on a section exposed in a shaft sunk at Evergreen on the James River.

1843

Conrad, T. A. Description of a New Genus and twenty-nine new Miocene and one Eocene Fossil Shells of the United States.

Proc. Acad. Nat. Sci., Phila., vol. i, pp. 305-311, 1843.

Six new species of Miocene fossils from Petersburg, Smithfield and James River are described.

——— Descriptions of Nineteen Species of Tertiary Fossils of Virginia and North Carolina.

Proc. Acad. Nat. Sci., Phila., vol. i, pp. 323-329, 1843.

Several new species of fossils from Petersburg, Coggins Point, and the Pamunkey River in Kent County, are described.

Rogers, W. B. On Limits of Infusorial Stratum in Virginia.

Amer. Jour. Sci., vol. xlv, pp. 313-314, 1843.

In a letter the author reports that the infusorial stratum has been traced entirely across the state. In some places it rests upon the Eocene at other times upon Miocene. He therefore concludes that it should be referred to a position within and near the bottom of the Miocene, although he doubts whether the infusorial strata all occur at exactly the same horizon. Many imperfectly carbonized vegetable remains which "seem to be referable to creeping and cryptogamous plants" are reported to occur in great abundance at some localities.

Tuomey, M. Notice of the Discovery of a new Locality of the "Infusorial Stratum."

Amer. Jour. Sci., vol. xliv, pp. 339-341, 1843.

The writer describes a deposit of the "infusorial stratum" within the city limits of Petersburg, 30 feet in thickness, and containing the casts of Pectens, resting upon the Eocene. The author definitely refers the infusorial stratum to the Miocene and correlates it with the Richmond bed on the basis of the microscopic fossils.

1844

Bailey, J. W. Account of some new Infusorial Forms Discovered in the Fossil Infusoria from Petersburg, Va., and Piscataway, Md.

Amer. Jour. Sci., vol. xlvi, pp. 137-141, pl. iii. 1844.

Several new species are described and figured.

Ehrenberg, C. G. Ueber zwei neue Lager von Gebirgsmessen aus Infusorien als Meeres-Absatz in Nord Amerika und eine Vergleichung derselben mit den organischen Kreide-Gebilden in Europe und Afrika.

Bericht k. p. akad. Wiss., Berlin, pp. 57-97, 1844.

Review Amer. Jour. Sci., vol. xlviii, pp. 201-204, 1845, by J. W. Bailey.

The author describes 112 species of diatoms in the infusorial earth of Richmond, and 67 from the deposit at Petersburg, of which 46 are common to the two localities.

Rogers, H. D. Address (on American Geology, and Present Condition of Geological Research in the United States).

Amer. Jour. Sci., vol. xlvii, pp. 137-160, 247-278, 1844.

A brief review of the geology of Eastern Virginia is given.

1845

Bailey, J. W. Notice of some New Localities of Infusoria, Fossil and Recent.

Amer. Jour. Sci., vol. xlviii, pp. 321-343, pl. iv, 1845.

Gives tables of all known species then described from Petersburg and Richmond.

Conrad, T. A. Fossils of the (Medial Tertiary or) Miocene Formation of the United States, No. 3.

Pp. 57-80, pls. 30-45, Phila., 1845. Republished by W. H. Dall, Washington, 1893.

Fossils from Petersburg, City Point, Prince George County, Ware River in Gloucester County, Pamunkey River in Kent County, Yorktown, Surrey County, Suffolk, and Urbanna, are described and figured.

LONSDALE, W. Indications of Climate Afforded by Miocene Corals of Virginia.

Quar. Jour. Geol. Soc., London, vol. i, pp. 427-429, 1845.

The author believes that the climate in the Virginia region during the Miocene was somewhat warmer than the present climate in the Mediterranean region.

LYELL, CHARLES. Observations on the White Limestone and other Eocene or Older Tertiary Formations of Virginia, South Carolina, and Georgia.

Quar. Jour. Geol. Soc., London, vol. i, pp. 429-442, 1845; Proc. Geol. Soc., London, vol. iv, pp. 563-575, 1845.

The author gives a description of the Eocene deposits of the James River, as well as of the Richmond and Petersburg areas. The occurrence of fossil species similar to Euorpean forms is mentioned.

——— On the Miocene Tertiary strata of Maryland, Virginia, and of North and South Carolina.

Quar. Jour. Geol. Soc., London, vol. i, pp. 413-427, 1845; Proc. Geol. Soc., London, vol. iv, pp. 547-563, 1845.

The author points out many similarities between the Miocene strata of Europe and North America in stratigraphic relations and fossil remains. Many localities on the James River where the strata are well exposed are described.

——— Travels in North America in the years 1841-2; with Geological Observations on the United States, Canada, and Nova Scotia.

2 vols., 12°, New York, 1845.

In a trip down the James River the author studied the Miocene deposits at Richmond, City Point, Evergreen, Grove Landing and Williamsburg. One hundred and forty-seven species of fossils were collected, most of which belong to genera recognized in the Miocene of Europe. Nine species are common to the two countries. The closer resemblance to the Miocene of the Loire and Gironde in France than to the Crag of England, is noted. A general description is given of the Dismal Swamp.

1846

CONRAD, T. A. Tertiary Fossil Shells.

Proc. Acad. Nat. Sci., Phila., vol. iii, pp. 19-27, 1 pl. 1846.

Two new species of Miocene shells from Suffolk and Yorktown and one Eocene fossil from City Point are described and figured.

CONRAD, T. A. Descriptions of eight new Fossil Shells of the United States.

Proc. Acad. Nat. Sci., Phila., vol. ii, pp. 173-174, 1846.

One Miocene shell from Petersburg and four Eocene forms from Hanover and Stafford counties are described.

1850

WYMAN, JEFFRIES. Notice of Remains of Vertebrated Animals found at Richmond, Virginia.

Amer. Jour. Sci. (n. s.), vol. x, pp. 228-235, 1850.

Bones of seals, whales, crocodiles, and many fishes are described from the Tertiary deposits along Shockoe Creek, Richmond. Most of them were probably derived from the Miocene strata, but some may have been contained in the Eocene deposits.

1852

LESQUEREUX, LEO. Ueber die Torfbildung un grossen Dismal-Swamp.

Geol. Gesell. Zeit., vol. iv, pp. 695-697, 1852.

The vegetation of the Dismal Swamp is described and the formation of the vegetable debris underlying the swamp discussed.

1853

CONRAD, T. A. Monograph on the genus Fulgur.

Proc. Acad. Nat. Sci., Phila., vol. vi, pp. 316-319, 1853.

Fulgur maximum and *F. incile* from Yorktown are described.

HITCHCOCK, EDWARD. Outline of the Geology of the Globe and of the United States in particular with two Geological maps, etc.

8°. Boston. 1853; 2d edit., 1854; 3d edit., 1856.

Brief descriptions of the Tertiary strata of Virginia are given.

MARCOU, JULES. A Geological Map of the United States and the British Provinces of North America with an explanatory text, etc.

8°, Boston, 1853.

Contains brief references to Virginia.

1854

WYMAN, JEFFRIES. Beak of a Fossil Fish (Icthiophorus) found in the Tertiary Deposit at Richmond, Va., communicated Oct. 6, 1852.

Proc. Boston Soc. Nat. Hist., vol. iv, p. 260, 1854.

Specimen said to resemble a sword-fish and probably belongs to undescribed species.

1856

EHRENBERG, C. G. Zur Mikrogeologie das Erden und Felsen Schaffende Wirken des unsichtbar kleinen selbstandigen Lebens auf der Erde.

2 vols. and atlas, roy. folio, 41 pls. Leipzig, 1854-56.

This work contains admirable descriptions and illustrations of over 100 species of diatoms from the infusorial earth of Richmond and other places in Virginia.

1861

Conrad, T. A. Fossils of the (Medial Tertiary or) Miocene Formation of the United States.

No. 4, pp. 81-89, pls. 45-49. Index to parts 1-4, Phila., 1861 (?) Republished by W. H. Dall, Washington, 1893.

Fossils from Petersburg, Yorktown, Smithfield and Suffolk are described and figured.

Rogers, W. B. Infusorial Earth from the Tertiary of Virginia and Maryland. (Read May 4, 1859.)

Proc. Boston Soc. Nat. Hist., vol. vii, pp. 59-64, 1861.

The stratigraphic relations, the lithologic characters, and the fossil contents of the diatomaceous earth strata exposed along Shockoe Creek, Richmond, are described in considerable detail.

1863

Conrad, T. A. Catalogue of the Miocene Shells of the Atlantic Slope.

Proc. Acad. Nat. Sci., Phila., vol. xiv, pp. 559-582, 1863.

——— Descriptions of New, Recent, and Miocene Shells.

Proc. Acad. Nat. Sci., Phila., vol. xiv, pp. 583-586, 1863.

A few new Miocene shells from Virginia are described.

1864

Meek, F. B. Check List of the Invertebrate Fossils of North America. Miocene.

Smith, Misc. Coll., vol. vii, No. 183, 34 pp., 1864.

1866

Conrad, T. A. Illustrations of Miocene Fossils with Descriptions of New Species.

Amer. Jour. Conch., vol. ii, pp. 65-74, pls. 3, 4, 1866.

Some new species of shells from Smithfield, Yorktown, and James River are described and figured.

——— Descriptions of New Species of Tertiary, Cretaceous, and Recent Shells.

Amer. Jour. Conch., vol. ii, pp. 104-106, 1866.

Two new Miocene molluscan shells from Virginia are described.

Credner, **Hermann**. Geognostische Skizzen aus Virginia, Nord Amerika.

Geol. Gesell. Zeits., vol. xviii, pp. 77-85, 1866.

Reference is made to the diatomaceous earth at Richmond, and the characteristics of the Dismal Swamp are described.

1867

GILL, THEODORE. On the Genus Fulgur and its Allies.
Amer. Jour. Conch., vol. iii, pp. 141-152, 1867.
References are made to several forms from the Miocene of Virginia.

1868

CONRAD, T. A. Descriptions of Miocene shells of the Atlantic Slope.
Amer. Jour. Conch., vol. iv, pp. 64-68, pls. 5, 6. 1869.
Several Miocene shells from Virginia previously described are re-classified, described, and figured.

——— Descriptions of New Genera and Species of Miocene Shells with Notes on other Fossil and Recent Species.
Amer. Jour. Conch., vol. iii, pp. 257-270, pls. 19-24, 1868.
Among the new forms described are several from the Miocene of Virginia.

COPE, E. D. Second Contribution to the History of the Vertebrata of the Miocene Period of the United States.
Proc. Acad. Nat. Sci., Phila., vol. xx, pp. 184-194. 1869.
Some whale vertebræ from the Miocene of the Nomini Cliffs are described.

MAURY, M. F. Physical Survey of Virginia, vol. i, 90 pp., 1868; vol. ii, 142 pp., 1878. Richmond.
Contains references to the geological formations of the state.

1869

CONRAD, T. A. Descriptions of and References to Miocene Shells of the Atlantic Slope, and Descriptions of Two New Supposed Cretaceous Species.
Amer. Jour. Conch., vol. iv, pp. 278-279, pls. 19, 20, 1869.
Callista densata from Petersburg and *Caryatis pilonema* are described and figured.

——— Descriptions of Miocene, Eocene and Cretaceous shells.
Amer. Jour. Conch., vol. v, pp. 39-45, pls. 1, 2, 1869.
Callista virginiana from the Miocene of Petersburg is described and figured.

COPE, E. D. Third Contribution to the Fauna of the Miocene Period of the United States.
Proc. Acad. Nat. Sci., Phila., vol. xxi, pp. 6-12, 1869.
A whale and a crocodile are described from fragments of the skeletons found in the Miocene strata of Virginia.

LEIDY, JOSEPH. Synopsis of Extinct Mammalia of North America.
Jour. Acad. Nat. Sci., Phila., (n. s.), vol. vii, pp. 363-472 with pls., 1869.

Cetacean remains from the Miocene of Westmoreland County, Richmond and City Point are described and figured. The statement is made that remains of walrus have been found in the superficial deposits of Accomac County.

1871

COPE, E. D. Synopsis of the Extinct Batrachia, Reptilia, and Aves of North America.

Trans. Amer. Philos. Soc., vol. xiv, pp. 1-252.

Mention is made of the beak of an Eocene fish *Cœlorhynchus ornatus* Leidy found near Petersburg, and a crocodile from "Eocene" of Eastern Virginia.

1872

SHALER, N. S. On the Causes which have led to the Production of Cape Hatteras.

Proc. Boston Soc. Nat. Hist., vol. xiv, pp. 110-123, 1872.

Abstr. Amer. Nat., vol. v, pp. 178-181, 1871.

The author believes that Delaware and Chesapeake bays were excavated by streams of ice which poured down the valleys of the Delaware and Susquehanna rivers during the Ice Age and the resulting debris was dropped farther south, forming Cape Hatteras and the eastern part of Virginia. The difference in topography south of the James River is supposed to be due to a recent subsidence of that region which was contemporaneous with the uplift of the northern part of the country on the melting of the ice sheet.

1873

HOTCHKISS, JED. On the Virginias; their Agricultural, Mineral, and Commercial Resources.

Soc. Arts (London) Jour., vol. xxi, pp. 238-251, 1873.

The article contains a brief description of the "Tide-water Country."

1875

WEBSTER, N. B. On the Physical and Geological Characteristics of the Great Dismal Swamp and the Eastern Counties of Virginia.

Amer. Nat., vol. ix, pp. 260-262, 1875.

The writer supposes that the basin of Lake Drummond was formed by the burning of the peat at some time in the past and the depression resulting was later filled with water. "The perpendicular banks of the lake and the charred stumps that have been found at the bottom confirm this supposition."

1876

CORYELL, MARTIN. Diatomaceous Sands of Richmond, Va.

Trans. Amer. Inst. Min. Eng., vol. iv, pp. 230-232, pl., 1876.

The Virginias, vol. ii, pp. 6-7.

The brief article is accompanied by a profile showing the geological structure of Church Hill between Shockoe and Gillies creeks.

HOTCHKISS, JED. Virginia: A geological and political summary, embracing a description of the State, its geology, soils, minerals, climate, etc., 319 pp., 4 maps.

Richmond, 1876. Not seen.

1877

ROGERS, WM. B. On the Gravel and Cobble-Stone Deposits of Virginia and the Middle States.

Proc. Boston Soc. Nat. Hist., vol. xviii, pp. 101-106, 1877.

Reprint of Reports on the Geology of the Virginias, pp. 709-713, New York, 1884. Abstr. Amer. Jour. Sci., 3d ser., vol. ii, pp. 60-61, 1876.

The lithological characteristics of the superficial deposits (Pleistocene) are described, and also their stratigraphic relation to the underlying strata. The author supposes that there is some close connection between the gravels and the glacial drifts of the northern states; either the materials represent transported and water-deposited glacial drift or merely the coarse river sediments brought down by the flooded rivers during the glacial period. The resemblance of the superficial deposits and those beds referred to the Upper Secondary (Potomac) is noted. The latter are considered to be Jurassic in age.

STODDER, CHARLES. A Contribution to Microgeology. Read Dec. 8, 1875.

Proc. Boston Soc. Nat. Hist., vol. xviii, pp. 206-209, 1877.

Abstr. Amer. Jour. Sci., 3d ser., vol. ii, pp. 493, 494, 1876.

The writer gives a list of 50 species of diatoms and 6 species of rhizopods found in the diatomaceous earth at Richmond. He reports that the upper strata lack many forms found in the lower layers.

1879

FONTAINE, WILLIAM M. Notes on the Mesozoic Strata of Virginia.

Amer. Jour. Sci., 3d ser., vol. xvii, pp. 25-39, 151-157, 229-239, 1879. Abstr. Neues Jahrbuch, pp. 137-138, 1881.

The Potomac deposits and their fossils are described briefly and the suggestion is made that perhaps the deposits were found during a Mesozoic ice age. The author quotes Lyell as noting the resemblance between these deposits and the northern Glacial Drift.

HEINRICH, OSWALD J. The Mesozoic Formation in Virginia.

Trans. Amer. Inst. Min. Eng., vol. vi, pp. 227-274, pl. 1879.

The Virginias, vol. i, pp. 120-126, 142-145, 155, 176-177, 190-192, pl.

The limits of the Mesozoic formations including the Potomac deposits are given and their characteristics discussed briefly.

MACFARLANE, JAMES. An American Geological Railway Guide.

219 pp., New York, 1879; 2d edit., revised and enlarged, 426 pp. New York, 1890.

Contains many brief statements concerning the Coastal Plain region of Virginia.

POLLARD, THOMAS. A Handbook, 144 pp., Richmond. 1879.

Bound in 22d. Ann. Rept. of Commissioner of Agriculture of the State of Virginia, Richmond, 1879.

Not seen.

1880

MICHELS, JOHN. The Richmond Diatomaceous Earth.

Science, vol. i, pp. 222, 1880.

The writer describes the occurrence of the diatomaceous earth and its general characteristics. It is said to consist of 10 per cent. unbroken forms of diatoms, 25 per cent. white sand, and the balance white clay.

1882

FONTAINE, WILLIAM M. The Artesian Well at Fort Monroe, Va.

The Virginias, vol. iii, pp. 18, 19, 1882.

The combined Eocene and Miocene strata in this well have a thickness of at least 800 feet. At a depth of 851 feet the boring was doubtless in Mesozoic strata, and at 885 feet the plant-bearing clay exposed at Dutch Gap was encountered.

ROGERS, WM. B. The Infusorial Deposits of Virginia in the Fort Monroe Artesian Well.

The Virginias, vol, iii, pp. 151, 152, 1882. Reprint of Reports on the Geology of the Virginias, pp. 731-736, New York, 1884.

Of 40 species of diatoms from the infusorial stratum reached at a depth of 558 feet, Mr. Samuel Wells reports that 29 are identical with species found at Richmond, thus seeming to prove that they come from the same stratum. The presence of Cretaceous strata between the Eocene and Jurasso-Cretaceous strata is also revealed in the same well section.

1883

HEILPRIN, A. On the Relative Ages and Classification of the Post-Eocene Tertiary Deposits of the Atlantic Slope.

Proc. Acad. Nat. Sci., Phila., vol. xxxiv, pp. 150-186, 1883.

Abstr. Amer. Nat., vol. xvii, pp. 308, 309, 1883; Amer. Jour. Sci., 3d ser., vol. xxiv, pp. 228, 229, 1882.

From a comparison of the fossils from the Miocene of Maryland, Virginia, and North and South Carolina, the author concludes that the Miocene should be divided into three formations—the Marylandian, including the oldest of the Maryland and Virginia Miocene strata, the Virginian, including the upper strata in those states, and the Carolinian, including the deposits of the Carolinas.

1884

HEILPRIN, A. Contributions to the Tertiary Geology and Paleontology of the United States.

117 pp., map. 4°, Phila., 1884.

The portions referring to Virginia are reprints of previous published articles mentioned above. On the map which accompanies the report a large area is shown as Carolinian, the upper division of the Atlantic Coast Miocene.

——— The Tertiary Geology of the Eastern and Southern United States.

Jour. Acad. Nat. Sci., Phila., vol. ix, pp. 115-154, map, 1884.

The geographical distribution of the Eocene and Miocene deposits are given. The Eocene deposits are referred to the Eo-Lignitic and Buhrstone formations of the southern states, while the Miocene deposits are grouped in the divisions of Marylandian and Virginian. The author thinks that possibly the Miocene deposits about Yorktown and Suffolk represent a later division which he has called Carolinian because of its development in the Carolinas.

ROGERS, WM. B. A Reprint of Annual Reports and other Papers on the Geology of the Virginias.

xv+832 pp., pls., maps, New York, 1884.

The various articles contained in this volume in which references are made to the Coastal Plain province have been given on preceding pages.

1885

HARRISON, RANDOLPH. Handbook of Virginia.

4th edit., 182 pp., map, pl., Richmond, 1885.

6th edit., 1886.

Not seen.

1888

HEILPRIN, A. The Classification of the Post-Cretaceous Deposits.

Proc. Acad. Nat. Sci., Phila., pp. 314-322, 1888.

The Eocene is divided into the Eo-Lignitic, Buhrstone, Claibornian, and Jacksonian and the Miocene into the Marylandian, Virginian, and Carolinian.

MCGEE, W J The Columbia Formation.

Proc. Amer. Assoc. Adv. Sci., vol. xxxvi, pp. 221-222, 1888.

The author divides the Pleistocene into two classes, the delta deposits laid down along the inland margin of the Coastal Plain by the Middle Atlantic slope rivers during a period of submergence ranging from 100 to 450 feet, and the terraced littoral deposits connecting and graduating into the deltas and covering the remainder of the Coastal Plain to the Atlantic Ocean. A bipartition of the deposits is frequently apparent and these two divisions are supposed to be contemporaneous with two ice-sheets which covered the northern portion of the country during Pleistocene time.

——— Three Formations of the Middle Atlantic Slope.

Amer. Jour. Sci., 3d ser., vol. xxxv, pp. 120-143, 328-330, 367-388, 448-466, pls. 2, 6-7; Abstr. Nature, vol. xxxviii, pp. 91, 190; Amer. Geol., vol. ii, pp. 129-131, 1888.

The three formations which are described in considerable detail are, (1) the Potomac (now divided into four formations); (2) the Appomattox (now called the Lafayette); and (3) the Columbia (now divided into three formations). The views expressed in this paper are but slightly at variance with those held by the authors of this report.

WARD, L. F. Evidence of the Fossil Plants as to the Age of the Potomac Formation.

Amer. Jour. Sci., 3d ser., vol. xxxvi, pp. 119-131, 1888. Abstr. Nature, vol. xxxviii, p. 462. 1888.

The author concludes in regard to the Potomac formation that "if the stratigraphical relations and the animal remains shall finally require its reference to the Jurassic, the plants do not present any serious obstacle to such reference."

1889

CURTICE, COOPER. Oriskany Drift near Washington, D. C.

Amer. Geol., vol. iii, pp. 223-225, 1889.

The writer states that he found water-worn pebbles and cobbles near Alexandria and Mt. Vernon carrying fossils of Oriskany age. Nine genera and eight species have been determined. The writer states that the cobbles come from the Potomac but it is not improbable that they came from the Columbia deposits. They were transported from the region beyond the Blue Ridge.

FONTAINE, WILLIAM M. The Potomac or younger Mesozoic Flora.

U. S. Geol. Survey, Monograph, vol. xv, pt. i, 377 pp.; pt. ii, 180 pls., Washington, 1889.

The monograph contains a description of the Potomac deposits of Virginia in which the lithologic characters of the deposits and their geographic occurrence are discussed in considerable detail. Three hundred and sixty-five species of fossil plants, most of them new, are described and figured.

KNOWLTON, F. H. Fossil Wood and Lignite of the Potomac Formation.

Bull. U. S. Geol. Survey, No. 56, 72 pp., 7 pls., Washington, 1889.

The author described the organic remains of the Potomac and their method of occurrence and gives a detailed description of the microscopic appearance of five new species of silicified wood, four of which were obtained from the Potomac strata of Virginia.

——— The Fossil Wood and Lignites of the Potomac Formation.

Amer. Geol., vol. iii, pp. 99-106, 1889.

After a careful microscopic examination of the silicified wood and lignite the author concludes that all belong to the conifers. The cells of the lignite have been so much distorted and metamorphosed that the specific determinations could not be made. The silicified specimens are very perfectly preserved and belong to two genera *Cupressinoxylon* with four species and *Araucarioxylon* with a single species.

1890

CLARK, WILLIAM B. Third Annual Geological Expedition into Southern Maryland and Virginia.

Johns Hopkins Univ. Circulars, vol. x, No. 81, pp. 69-71.

On the trip various localities along the Potomac, York, and James rivers were visited for the study of the Cretaceous, Tertiary, and Quaternary formations of the Coastal Plain. Sections of the strata at Aquia Creek, Nomini Cliffs, Yorktown, and Grove Wharf are given.

Cope, E. D. The Cetacea.

Amer. Nat., vol. xxiv, pp. 599-616, pls. 20-23.

In a list of extinct Cetacea of North America some forms from the Miocene of Virginia are named.

Shaler, Nathaniel S. General Account of the Fresh-water Morasses of the United States, with a Description of the Dismal Swamp District of Virginia and North Carolina.

U. S. Geol. Survey, 10th Ann. Rept., pp. 255-339, pls. 6-19. Washington. 1890. Abstr., pp. 15-16.

The geology, topography, and general character of the vegetation of the Dismal Swamp are discussed in considerable detail. A list of 29 species of shells obtained from the vicinity of the Jericho Canal are given of which 24 belong to living and 5 to extinct species. The conclusion is reached that the fossiliferous beds beneath the swamp are Pliocene in age.

1891

Darton, N. H. Mesozoic and Cenozoic Formations of Eastern Virginia and Maryland.

Bull. Geol. Soc. Amer., vol. ii, pp. 431-450, pl. 16, 1891.

The geographical distribution, characteristics and stratigraphic relations of the Pamunkey (Eocene), Chesapeake (Miocene), and Appomattox (Lafayette) formations in Maryland and Virginia are discussed.

Lindenkohl, A. Notes on the Submarine Channel of the Hudson River and other Evidences of Post-Glacial Subsidence of the Middle Atlantic Coast Region.

Amer. Jour. Sci., 3d ser., vol. xli, pp. 489-499, 18 pls. 1891.

The author describes the submerged channel of Chesapeake Bay.

1891

McGee, W J With the Collaboration of G. H. Williams, N. H. Darton and B. Willis.

The Geology of Washington and vicinity. Guide to Washington, prepared for the International Cong. Geol., 5th session. Washington, 1891.

Contains a general description of the physiography and the geological formations of the Coastal Plain.

——— The Lafayette Formation.

U. S. Geol. Survey, 12th Ann. Rept., pp. 347-521, 1891.

The article embraces a general description of the physiography and geology of the Coastal Plain and a detailed description of the lithologic characteristics of the Lafayette formation, together with its geographical distribution, its economic importance, and the geologic history recorded in the formation.

WHITE, CHARLES A. Correlation Papers—Cretaceous.

U. S. Geol. Survey, Bull. No. 82, 273 pp., 3 pls., Washington, 1891.

This bulletin contains a brief résumé of the previously published articles on the Potomac deposits of Virginia.

WOOLMAN, LEWIS. Note on the Extension Southward of Diatomaceous Clays and the Occurrence there of Flowing Wells.

Geol. Surv. of New Jersey, Report for 1890, pp. 275-276, 1891.

The author mentions many localities in Virginia where diatomaceous earth outcrops and other places where it has been reached in well borings.

1892

CLARK, W. B. Correlation Papers—Eocene.

U. S. Geol. Survey, Bull. No. 83, 159 pp., 2 pls., 1892; Abstrs. Amer. Geol., vol. xii, p. 379, 1893; Amer. Nat., vol. xxvi, pp. 330-332, 1892.

The paper embodies an historical review of the literature and a general summary of all existing knowledge concerning the Eocene strata of the United States. The Virginia deposits are briefly described.

DALL, W. H. AND HARRIS, G. D. Correlation Papers. Neocene.

U. S. Geol. Survey, Bull. No. 84, 349 pp., 3 pls., 43 figs., 1892.

Contains a general summary of all existing information concerning the Miocene and Pliocene deposits of Virginia based principally upon the work of Rogers and Conrad.

1893

CLARK, W. B. The Eocene of the United States.

Johns Hopkins Univ. Circ., vol. xii, pp. 50, 51, 1893.

Contains a brief synopsis of the Eocene Correlation bulletin No. 83 of the United States Geological Survey.

1894

DARTON, N. H. Fredericksburg Folio, Virginia-Maryland.

U. S. Geol. Survey, Geol. Atlas of U. S., Folio No. 13, 1894.

The topography, geology, and economic resources of the Fredericksburg quadrangle, which includes all of King George County and considerable portions of Stafford, Spottsylvania, Caroline, Essex, and Westmoreland counties, are discussed in the text and represented on the accompanying maps drawn to the scale of 1 :125,000.

——— On Fossils in the Lafayette Formation in Virginia.

Amer. Geol., vol. ix, pp. 181-183, 1892.

The Lafayette is reported to extend down the peninsula from the Piedmont Plateau almost to Chesapeake Bay. Water-worn shells are reported from the Lafayette deposits near Heathsville, Northumberland County, but it is possible, if not probable, that they were derived from the Miocene. The fossils were too poorly preserved to be definitely determined.

——— Outline of Cenozoic History of a Portion of the Middle Atlantic Slope.

Jour. Geol., vol. ii, pp. 568-587, 1894.

The Cenozoic history of the Middle Atlantic Coastal Plain is described and the development of the present topography discussed. A small scale map shows the distribution of the Columbia deposits in Virginia.

Harris, Gilbert D. On the Geological Position of the Eocene Deposits of Maryland and Virginia.

Amer. Jour. Sci., 3d ser., vol. xlvii, pp. 301-304, figs. 1-3, 1894.

On the basis of the fossils the Eocene strata of Maryland and Virginia are correlated with the Lignitic stage of the southern states.

1895

Bagg, R. M. Protozoa (Eocene Fauna of the Middle Atlantic Slope).

Johns Hopkins Univ. Circ., vol. xv, p. 6, 1895.

A list of 21 species of foraminifera from Woodstock and the Pamunkey River is given of which one is a new species and is described.

Clark, W. B. Contributions to the Eocene Fauna of the Middle Atlantic Slope.

Johns Hopkins Univ. Circ., vol. xv, pp. 3-6, 1895.

From a study of the Eocene fauna of Maryland and Virginia the author divides the Eocene strata of these states into two stages, the Aquia Creek and Woodstock. He believes that they represent the Lignitic, Buhrstone, Claiborne, and possibly part of the White Limestone of the Alabama region.

——— Descriptions of the Geological Excursions made during the Spring of 1895.

Johns Hopkins Circ., vol. xv, pp. 1-3, 1895.

The outcrops of the Potomac Eocene and Miocene strata along the Potomac River are briefly described.

1895

Cope, E. D. Fourth Contribution to the Marine Fauna of the Miocene Period of the United States.

Proc. Amer. Philos. Soc., vol. xxiv, pp. 135-155, pl. 6.

***Cetotherium megalophysum*, a new species from the Miocene at Tar Bay on the James River is described.**

Darton, N. H. Artesian Well Prospects in Eastern Virginia, Maryland and Delaware.

Amer. Inst. Min. Engrs. Trans., vol. xxiv, pp. 372-397, pls. 1-2, 1895.

The geological occurrence of artesian water in the Coastal Plain is discussed and the records of many deep wells, especially those in the vicinity of Norfolk, are given.

GANE, HENRY STEWART. A Contribution to the Neocene Corals of the United States.

Johns Hopkins Univ. Circ., vol. xv, pp. 8-10, 1895.

The author believes "that the corals of the Neocene flourished as shallow-water forms with preponderating reef-building tendencies." Five species from the Miocene of Virginia are described, one of which is new.

VAUGHAN, T. WAYLAND. Coelenterata (Eocene Fauna of the Middle Atlantic Slope).

Johns Hopkins Univ. Circ., vol. xv, p. 6, 1895.

Describes two new species of corals from the Eocene deposits at Aquia and Potomac creeks, Virginia.

1896

BAGG, R. M. (Protozoa from the Eocene Deposits of Delaware, Maryland, and Virginia.)

U. S. Geol. Survey, Bull. No. 141, pp. 91, 92, 1896.

A list of 21 species of foraminifera from the Eocene deposits of Virginia is given, 16 from Woodstock and 5 from the Pamunkey River.

CLARK, W. B. The Eocene Deposits of the Middle Atlantic Slope in Delaware, Maryland, and Virginia.

U. S. Geol. Surv., Bull. No. 141, 167 pp., 40 pls., 1896. Review by C. R. Keyes, Jour. Geol., vol. v, pp. 310-312, 1897.

The paper contains a bibliography and historical review of the literature of the Eocene of the Middle Atlantic region and a discussion of the stratigraphy and paleontological characteristics of the deposits. Two distinct faunas, the Aquia Creek and Woodstock are recognized. The most important fossils are described and figured.

——— The Potomac River Section of the Middle Atlantic Coast Eocene.

Amer. Jour. Sci., 4th ser., vol. i, pp. 365-374, 1896.

The lithology and paleontology of the Eocene strata of the Potomac River basin are described. The author believes they represent a single geological unit, the Pamunkey formation with two clearly defined faunal zones, the Aquia Creek stage and the Woodstock stage.

COPE, E. D. Sixth Contribution to the Knowledge of the Marine Miocene Fauna of North America.

Proc. Amer. Philos. Soc., vol. xxxv, pp. 139-146, pls. 11, 12.

***Syllomus crispatus* gen. and sp. new from the Miocene along the Pamunkey River, *Rhegnopsis palæatlanticus* Leidy from the Miocene of Southeastern Virginia, and *Cetotherium leptocentrum* Cope from the James River are described and figured.**

DARTON, N. H. Artesian Well Prospects in the Atlantic Coastal Plain Region.

U. S. Geol. Survey, Bull. No. 138, 228 pp., 19 pls., 1896.

Contains much information concerning the deep wells and the water-bearing strata of the Coastal Plain of Virginia.

——— Nomini Folio, Maryland-Virginia.

U. S. Geol. Survey, Geol. Atlas of U. S., Folio No. 23, 1896.

The topography, geology, and economic resources of the Nomini quadrangle which embraces a considerable portion of Westmoreland, Richmond, and Essex counties are discussed in the text and represented on maps drawn to the scale of 1 :125,000.

FONTAINE, WILLIAM M. The Potomac Formation in Virginia.

U. S. Geol. Survey, Bull. No. 145, 149 pp., 2 pls., 1896.

The author describes in considerable detail all the principal exposures of the Potomac deposits in Virginia.

VAUGHAN, T. WAYLAND. Coelenterata from the Eocene Deposits of Delaware, Maryland, and Virginia.

U. S. Geol. Survey, Bull. No. 141, pp. 89-91, 1896.

The description of three species of corals from Aquia Creek and one from the Pamunkey River in New Kent County are given.

1897

ALDRICH, T. H. Notes on Eocene Mollusca, with Descriptions of new species.

Bull. Amer. Pal., vol. ii, No. 8, 26 pp., 5 pls., Ithaca, 1897.

Crassatella declivis Heilprin from Aquia Creek and *Ringicula dalli* Clark from Woodstock are figured.

CLARK, W. B. Outline of Present Knowledge of the Physical Features of Maryland, Embracing an Account of the Physiography, Geology, and Mineral Resources.

Md. Geol. Survey, vol. i, pp. 141-228, pls. 6-13, 1897.

Contains many references to the Coastal Plain deposits of Virginia.

CLARK, W. B. AND BIBBINS, A. The Stratigraphy of the Potomac Group in Maryland.

Jour. Geol., vol. v, pp. 479-506, 1897.

A new classification of the Potomac deposits is proposed by which they are divided into the Patuxent, Arundel, Patapsco, and Raritan formations on stratigraphic grounds. The first two are doubtfully referred to the Jurassic, the last two to the Cretaceous.

WATSON, THOMAS L. A Bibliography of the Geological, Mineralogical and Paleontological Literature of the State of Virginia.

Bull. Amer. Pal., vol. ii, No. 7, 109 pp., 1897.

Gives a list of journals consulted and a bibliography arranged alphabetically by names of authors.

1898

BAGG, R. M. The Tertiary and Pleistocene Foraminifera of the Middle Atlantic Slope.

Bull. Amer. Pal., vol. ii, No. 10, 68 pp., 3 pls., 1898.

Fifty-six species of Eocene, Miocene, and Pleistocene foraminifera are described and figured, of which many were obtained from the Virginia deposits.

DALL, W. H. A Table of North American Tertiary Horizons correlated with one another and with those of Western Europe, with Annotations.

U. S. Geol. Survey, 18th Ann. Rept., pt. ii, pp. 327-348, 1898.

The Eocene beds of Virginia are placed in the Chickasawan stage near the base of the Eocene and correlated with the Suessonian of Europe and the Miocene deposits are correlated with the Helvetian beds of Europe.

DARTON, N. H. Discovery of Marine Cretaceous in Boring at Norfolk, Virginia.

Abstr. Geol. Soc. Amer. Bull., vol. ix, pp. 414-416.

The presence of marine Cretaceous shells is reported in a deep well at Norfolk between the depths of 715 and 775 feet and at Lamberts Point between 563 and 616 feet.

1899

GLENN, L. C. The Hatteras Axis in Triassic and Miocene Time.

Amer. Geol., vol. xxiii, pp. 375-379, 1899.

The view is expressed that the region in the vicinity of Cape Hatteras was not submerged during early Miocene time and this accounts for the discontinuity of the lower Miocene deposits of Virginia with those of the Carolinas.

WOOLMAN, LEWIS. Artesian Wells.

Ann. Rept. N. J. Geol. Survey for 1898, pp. 121-126, 1899.

Records of two artesian wells in the Coastal Plain of Virginia are given, one at Fairport in Northumberland County, and the other at Old Point Comfort. Marine Cretaceous fossils were found at depth of 640 feet at Fairport and at depth of 840 feet at Old Point Comfort. A list of Miocene forms from latter well is also given.

——— Fossil Mollusks and Diatoms from the Dismal Swamp, Virginia and North Carolina; Indication of the Geologic Age of the Deposits; with Notes on the Diatoms by Charles C. Boyer.

Proc. Acad. Nat. Sci., 1898, pp. 414-429, 1899.

Forty-nine species of mollusca were obtained form the Dismal Swamp near Wallaceton and Suffolk. Of these 7 species are Pliocene and pre-Pliocene forms, 16 species range from Miocene to Recent; 14 species are found in both Pliocene and Recent deposits; and 12 species are Pleistocene or Recent. From these facts the author concludes that the fossiliferous deposits underlying the Dismal Swamp are not older than late Pliocene and may be Pleistocene in age.

1900

BOYER, C. S. The Biddulphoid Forms of North American Diatomacea.

Proc. Acad. Nat. Sci., Phila., pp. 685-748, 1900.

Describes many forms occurring in the Miocene deposits of Virginia.

GANE, HENRY STEWART. Some Neocene Corals of the United States.

Proc. U. S. Nat. Mus., vol. xxii, pp. 179-198, pl. 15.

Some Miocene species from Virginia are described, one of which is also figured.

GANNETT, HENRY. Physiographic Types.

U. S. Geol. Survey Topog. Atlas of U. S., Folio No. 2, 1900.

The Norfolk topographic sheet is included in the folio to illustrate a coast swamp.

VAUGHAN, T. WAYLAND. The Eocene and Lower Oligocene Coral Faunas of the United States.

U. S. Geol. Survey, Monogr. xxxix, 263 pp., 24 pls., 1900.

Several species of corals from the Eocene deposits of Virginia are described and figured.

1901

CLARK, W. B. and others. Maryland Geological Survey. Eocene.

331 pp., 64 pls., Baltimore, 1901.

The Eocene deposits on the Potomac River in Virginia are discussed and many fossils from that region are described and figured.

DARTON, N. H. and KEITH, ARTHUR. Washington Folio, Dist. of Columbia, Maryland, Virginia.

U. S. Geol. Survey, Geol. Atlas of U. S., Folio No. 70, 1901.

The topography, geology, and economic resources of the Washington quadrangle, which includes a considerable area in Virginia are discussed in the text of the folio and represented on the accompanying maps drawn to the scale of 1 :62.500.

1902

DARTON, N. H. Norfolk Folio, Virginia-North Carolina.

U. S. Geol. Survey, Geol. Atlas of U. S., Folio No. 80, 1902.

The topography, geological formations, and economic resources of the Norfolk region are discussed and represented on accompanying maps drawn to the scale of 1 :125,000. A good description is given of the Dismal Swamp.

1903

RIES, HEINRICH. The Clays of the United States east of the Mississippi River.

U. S. Geol. Survey, Professional Paper No. 11, 298 pp., 9 pls., 11 figs., 1903.

Gives a very brief account of the geologic and geographic distribution of the clay deposits in the Coastal Plain of Virginia.

1904

CLARK, W. B. and others. Maryland Geological Survey. Miocene.

cxxxvii+543 pp., 135 pls., Baltimore, 1904.

Many references are made to the Miocene deposits of Virginia while the Virginia fossils are frequently mentioned. Most of the forms described from the Maryland deposits also occur in Virginia.

1905

Ward, Lester F. with the collaboration of Fontaine, W. M., Bibbins, A., and Wieland, G. R.

Status of the Mesozoic Floras of the United States. Mono. U. S. Geol. Survey, vol. xlviii, 616 pp., 119 pls., 11 figs.

The various plant-bearing beds of the Potomac deposits in Virginia are described and lists given of the plants occurring at each place. Most of the species named are described and figured. In a columnar section the Potomac deposits in Virginia are given a thickness of 525 feet, of which the lower 350 feet are designated as the James River and Rappahannock beds, and correlated with the Arundel and Patuxent formations; above are the Mount Vernon beds with a thickness of 25 feet and correlated with the base of the Patapsco formation; and at the top are the Brook beds, 150 feet in thickness, which are correlated with the upper part of the Patapsco formation. The author believes all of the Potomac strata are Cretaceous in age.

1906

Berry, Edward W. Pleistocene Plants from Virginia.

Torreya, vol. vi, pp. 88-90, 1906.

Contains brief description of the fruit of the hickory, grape, beech, cypress, and black gum found in the Pleistocene swamp deposits near Tappahannock on the Rappahannock River.

Berry, Edward W. and Gregory, William K. Prorosmarus alleni, a New Genus and Species of Walrus from the Upper Miocene of Yorktown, Virginia.

Amer. Jour. Sci., 4th ser., vol. xxi, pp. 444-450, figs. 1-4, 1906.

Contains a description of half of a lower jaw of a walrus found on the beach at Yorktown washed from the fossiliferous Miocene beds that form the cliffs at that point.

Clark, Wm. Bullock and Mathews, Edward B. Report on the Physical Features of Maryland.

Md. Geol. Surv., vol. vi, pt. 1, 1906, pp. 27-251, pls. 2-23.

Frequent references are made to Virginia and the relations of the entire Coastal Plain of which Virginia is a part.

Ries, Heinrich. The Clay Deposits of the Virginia Coastal Plain with a chapter on the Geology of the Virginia Coastal Plain by William Bullock Clark and Benjamin LeRoy Miller.

Geol. Survey of Virginia, Geol. ser., Bull. No. 2, 184 pp., 15 pls., 10 figs., 1906

Contains a detailed account of the localities in the Virginia Coastal Plain where the clay deposits are now being utilized and a brief sketch of the geology of the region.

Shattuck, G. B. Md. Geol. Survey. Pliocene and Pleistocene. 291 pp., 75 pls., Baltimore, 1906.

Many references are made to the Pliocene and Pleistocene deposits of Virginia. Most of the species described from the Maryland deposits also occur in Virginia.

1907

CLARK, WM. BULLOCK. The Classification adopted by the U. S. Geological Survey for the Cretaceous Deposits of New Jersey, Delaware, Maryland and Virginia.

Johns Hopkins University Circulars, new ser., 1907, No. 7, pp. 1-4 (589-592), Baltimore, 1907.

Contains a brief discussion of the Cretaceous formational names of the Northern Atlantic Coastal Plain.

WATSON, THOMAS L. Mineral Resources of Virginia. Virginia-Jamestown Exposition Commission, 1907.

xxxi+619 pp., 83 pls., 101 figs.

Describes the general geology and mineral resources of Virginia, including the Coastal Plain region.

1909

BERRY, EDWARD W. A Miocene Flora from the Virginia Coastal Plain.

Jour. Geol., vol. xvii, pp. 19-30, 11 figs., 1909.

Fourteen species of fossil plants, six of which are new ones, from the diatomaceous earth at Richmond are described. The writer states that the flora indicated the formation of the deposits near the shore of a marine body of water.

BERRY, EDWARD W. Pleistocene Swamp Deposits of Virginia.

Amer. Nat., 1909, vol. xliii, pp. 432-436, figs. 1, 2.

SMITH, BURNETT. Note on the Miocene Drum Fish *Pogonias multidentatus* Cope.

Amer. Jour. Sci., 4th ser., vol. xxviii, pp. 275-282, figs. 1-13, 1909.

Contains description and figures of this rare species which was originally described by Cope in 1869.

WATSON, THOMAS L. Annual Report on the Mineral Production of Virginia During the Calendar Year 1908.

Bulletin No. I-A Virginia Geological Survey, 141 pp., map and 25 figs, 1909.

1910

BERRY, EDWARD W. A Revision of the Fossil Plants of the genera Acrostichopteris, Tæniopteris, Nilsonia, and Sapindopsis from the Potomac Group.

Proc. U. S. Natl. Mus., vol. xxxviii, 1910, pp. 625-644.

———. A Revision of the Fossil Plants of the genus Nageiopsis of Fontaine.

Proc. U. S. Natl. Mus., vol. xxxviii, 1910, pp. 185-195, tf. 1, 2.

———. The epidermal characters of Frenelopsis ramosissima.
Bot. Gazette, vol. 1, 1910, pp. 305-309, tf. 1, 2.

———. Geologic relations of the Cretaceous Floras of Virginia and North Carolina.
Bull. Geol. Soc. Amer., vol. xx, 1908, pp. 655-659.
Abstr. Science, N. S. vol. xxix, p. 629, 1909.

CLARK, WM. BULLOCK. Results of a recent investigation of the coastal plain formations in the area between Massachusetts and North Carolina.
Bull. Geol. Soc. Amer., vol. xx, 1910, pp. 646-654.
Abstr. Science, N. S. vol. xxix, p. 629, 1909.

MILLER, BENJAMIN L. Erosion Intervals in the Tertiary of North Carolina and Virginia.
Bull. Geol. Soc. Amer., vol. xx, pp. 673-678.

1911

BERRY, EDWARD W. A Lower Cretaceous species of Schizæaceæ from eastern North America.
Annals of Botany, vol. xxv, 1911, pp. 193-198, tf. 1, pl. xii.

———. A revision of several genera of gymnospermous plants from the Potomac Group in Maryland and Virginia.
Proc. U. S. Natl. Mus., vol. xl, 1911, pp. 289-318.

———. A revision of the fossil ferns from the Potomac Group which have been referred to the genera Cladophlebis and Thyrsopteris.
Proc. U. S. Natl. Mus., vol. xli, 1911, pp. 307-332.

Besides the above named articles there are many brief references to the economic resources of the Virginia Coastal Plain in the statistical publications of the U. S. Geological Survey and in the special reports of the U. S. Census Office.

PHYSIOGRAPHY OF THE VIRGINIA COASTAL PLAIN

INTRODUCTORY.

As has been previously stated, the Coastal Plain falls naturally into two divisions, a submerged or submarine portion and an emerged or subaerial portion, the shore-line of the Atlantic Ocean forming the boundary between them. This line of demarcation, although apparently fixed, is in reality very changeable, for during the past geologic ages it has migrated back and forth across the Coastal Plain, at one time occupying a position well over on the Piedmont Plateau and at another far out to sea. At the present time there is reason to believe that the shore-line is encroaching on the land by a slow subsidence of the latter, but a few generations of men afford a scarcely long enough period in which to determine this point definitely.

SUBMARINE DIVISION.

GENERAL CHARACTERISTICS.

The submerged portion of the Coastal Plain may be described as a broad plain with a very even surface sloping gently seaward beneath sea level. In the vicinity of the edge of the continental shelf these characters are very noticeable, but as the land is approached the surface becomes decidedly undulating. Small hills, which appear as shoals, increase in number and in size as the water becomes shallower until they finally rise above the water's level. The slopes of these shoals are gentle and they are usually elliptical in shape with the long diameter parallel to the shore-line. If contour lines at intervals of one fathom should be drawn on the charts of the United States Coast and Geodetic Survey along the eastern shores of Virginia, they would be found to be roughly parallel to the shore-line, but there would be frequent irregularities and many closed contours marking the small submerged hillocks. Except near inlets where the tidal currents maintain a deeper channel in the center and have produced numerous hooks and spits, the one-fathom contour is a fairly constant line distant from the shore on an average of from one-eighth to one-quarter of a mile. The two-fathom line is about the same distance farther east while the succeeding lines for a distance of several miles are considerably farther apart and only again come nearer together as the edge of the continental shelf is approached.

The material covering the submarine Coastal Plain near the shore is primarily fine sand mixed with numerous broken shells, which furnish evidence of the abundance of molluscan forms inhabiting the region, while here and there occur local deposits of pebbles and also of blue mud. Seaward the deposits become finer until in the vicinity of the continental slope muddy deposits predominate.

OFF-SHORE BEACHES AND BARS.

As the large waves from the deeper parts of the Atlantic Ocean advance toward the land they finally reach a place where the lower part of the wave drags on the bottom. The unconsolidated material is carried landward until the wave finally breaks. The smaller wave current then continues to carry part of the fine sand forward. Some is carried back by the undertow current, while some is left heaped up in a ridge formed parallel to the advancing wave front. Thus in time a chain of sand-bars which may become considerable islands is formed a short distance from the former shore-line and with each succeeding storm these are either enlarged or cut away. As these increase ih size sand dunes form upon them and thus the elevation above the sea may become so great that the largest storm waves never sweep over them. Bordering the eastern shore of the State is a chain of long, narrow, low-lying sandy islands formed in this way, and separated from each other by narrow inlets through which the tide enters and leaves the lagoons formed back of the islands. Many of these islands are very narrow and scarcely rise above the water, but others are a mile or more in width and are inhabited by considerable colonies of fishermen. The most important of these islands are Chincoteague, Assateague, Metomkin, Paramores Beach, Hog, Cobbs, and Smith on which is located the Cape Charles light house.

COASTAL LAGOONS.

Between the sandy beaches just described and the shore is a series of shallow-water lagoons of variable width from one-half mile to six or eight miles. Bordering these on either side is usually a considerable belt of salt to fresh water marshes. The average depth of water is only three or four feet, except in the channels through which the tide enters and leaves. The amount of water flowing through the narrow inlets between the islands is so great that occasionally very strong tidal currents are produced, currents strong enough to scour out relatively deep channels. Thus the channel of Great Machipongo Inlet between Hog and Cobbs islands is in places over 60 feet in depth while that of Sand Shoal Inlet between Cobbs and Bone islands has a maximum depth of 72 feet. The bars and hooks formed off the mouths of these inlets and built up largely of material carried out from the lagoons are very changeable so that the buoys marking the channel approaches must be frequently shifted.

The lagoons are only temporary features as they are gradually being filled by the accumulation of vegetable material, by the debris carried from the mainland, and to a certain extent by the sand carried by the wind from the sandy beaches. If the land remains at its present level with respect to the ocean, these lagoons will ultimately disappear by this infilling and the sandy islands will be connected with the mainland as they are along many parts of the Atlantic coast at the present time.

SUBAERIAL DIVISION.

GENERAL CHARACTERISTICS.

The emerged portion of the Coastal Plain declines with gradually lessening slope from the Piedmont Plateau border to the shore-line. The highest portions of the Virginia Coastal Plain are found in Fairfax County near Washington. Southward the Western margin gradually declines in altitude. The outlier in Fairfax County already referred to covers a flat-topped divide almost 500 feet above sea level, while in Spottsylvania County similar deposits are found about 400 feet above sea level. In the southern portion of the State the greatest elevation of Coastal Plain deposits is probably little more than 200 feet. These differences in elevation are responsible for the much more diversified topography in the northern than in the southern portion of the State. The easterly slope of the Coastal Plain from the "fall-line" which near the western margin may reach 10 or 15 feet to the mile, or even more, gradually declines to less than a foot to the mile in the extreme eastern part of the State. On either side of Chesapeake Bay there are wide areas of monotonously flat lands only a few feet above the water level. The average elevation of the Virginia Coastal Plain is slightly more than 100 feet above tide.

TERRACES.

The topography of the Virginia Coastal Plain, although of low relief, is in reality more complex than at first appears, this complexity being due to a series of terraces which stretch across the region, each in succession wrapping about the preceding in concentric arrangement. These terraces are five in number and have been designated by the names of the formations whose deposits cover them. They are in order, from the highest to the lowest, the Lafayette, the Sunderland, the Wicomico, the Talbot, and the Recent.

Lafayette terrace.—The highest of the five terraces is known as the Lafayette. It is best developed in Virginia along the western margin of the province, capping the broader divides between the main streams. The surface of this terrace varies considerably in appearance according to its position. In some places in the interior of large areas where it is removed from the influence of streams, it is as flat and featureless as any portion of the Eastern Shore, but along the margins where it has been dissected by waterways, it has been transformed into a gently rolling country. Erosion has been so active since the formation of the Lafayette terrace that isolated remnants of the original surface are frequent, some of them occurring as outliers upon the Piedmont rocks, while other detached areas lie to the east of the main body. Could the intervening areas be filled in, we would have a continuous, gently-rolling to flat plain of variable width, extending from eastern Pennsylvania southward to Mexico.

The general slope of the Lafayette terrace is eastward toward the ocean and represents, as will be explained later, the gradual descent of a subaqueous terrace away from the shore-line out into deeper water. In some places the terrace has been slightly warped by earth movements and thus the normal slope is obscured. The highest portion of the Lafayette terrace thus far recognized in Virginia lies to the west of Falls Church in Fairfax County and has an elevation of between 480 and 500 feet above sea level. It gradually descends from this point to the eastward along the stream divides to an altitude of about 200 feet, where it ends at the escarpment marking the landward margin of the Sunderland terrace Added details regarding the distribution and character of this terrace will be given under the discussion of the Lafayette formation.

Sunderland terrace.—Bordering the Lafayette terrace at a lower level is the Sunderland terrace. It penetrates the former in re-entrants and is at times separated from it by a well-marked scarp line. This terrace surface has its greatest development in the central part of the province. From Stafford County to Greenesville County it is represented as a fringing terrace along the sides of larger valleys whose divides are formed by the Lafayette terrace. This relationship of the Sunderland to the Lafayette terrace is always found wherever the two occur in juxtaposition. The difference in altitude between them varies, generally becoming more marked to the westward toward the Coastal Plain border. The passage from the Lafayette to the Sunderland is gentle, but occasionally it is accomplished by means of an abrupt drop resembling in appearance a sea-cliff which has been more or less modified by subaerial erosion.

The same description applies to the surface of this terrace as to that of the Lafayette, namely, that in the interior where it has not been greatly affected by erosion, it still retains its original level, featureless character, but along the borders where it has been attacked by the headwaters of streams it has been transformed into a rolling country.

The Sunderland terrace reaches an altitude of about 200 to 250 feet above sea level where it abuts against the Lafayette terrace. From that line the surface slopes toward the larger streams as well as seaward, sometimes at the rate of several feet to the mile, at other times at the rate of only a few inches to the mile. In general, it may be stated that the greater portion of the Coastal Plain area of Virginia lying between 100 and 200 feet above sea level belongs to the Sunderland terrace. Could the Coastal Plain of Virginia be depressed 200 feet permitting the waters of the sea to cover the entire region below that elevation, the shore-line would more or less definitely define the present landward margin of the Sunderland terrace. Could the region then be uplifted 100 feet the resulting shore-line would approximately mark the eastward limit of the terrace.

Wicomico terrace.—Bordering the Sunderland terrace at a lower level is the Wicomico terrace. It bears the same relationship to the Sunderland terrace that the latter does to the Lafayette terrace in that it wraps about it as a border, extends up the larger stream valleys, and is separated from it by a well-defined line of low cliffs, especially in the northern portion of the State. In the eastern portion of the State from Northumberland County to Nansemond County it forms most of the flat-topped stream divides, while it is continued westward along the larger streams to the head of tide. The Wicomico terrace has suffered from erosion although less than the two older terraces but like them it no longer forms a continuous plain. In some places where streams have not yet cut the terrace it has a very flat surface, but elsewhere considerable portions have been entirely removed or cut up into a rolling country. The Wicomico terrace at its landward margin where it is in contact with the Sunderland has a nearly constant altitude of from 80 to 90 feet. From that line it slopes gradually eastward and to the larger valleys ending at the escarpment which represents the shore margin of the next lower or Talbot terrace.

Talbot terrace.—The lowest of the subaerial terraces is the Talbot. Like the other members of the series, it wraps about the preceding terrace like a border, penetrates it in re-entrants and is separated from the Wicomico terrace by a scarp line. This scarp line is very conspicuous in many parts of the region, sometimes with a height of 20 or more feet, at other times with a height of less than 10 feet. It is very prominent just to the west of the Dismal Swamp and in many places in the valleys of the estuaries. The Talbot terrace occupies practically the entire counties of Mathews, Elizabeth City, Norfolk, and Princess Anne on the Western Shore and all of the Eastern Shore. It is found also as a bordering terrace, more or less continuous, along most of the estuarine portions of the Potomac, Rappahannock, York, and James rivers. It has suffered less from erosion than any of the other terraces, because of its lower altitude and more recent formation, and maintains nearly everywhere its original surface almost unmodified by the present drainage.

The Talbot terrace although in general monotonously flat, contains some shallow depressions, the most noted of which is that occupied by the Dismal Swamp. In other places, especially on the Eastern Shore and in Princess Anne County, the surface has been rendered more or less irregular by recent sand dunes. The altitude of the Talbot terrace, where it abuts against the Wicomico terrace is usually about 40 feet. From its landward margin it slopes away toward the surrounding waters where it either terminates in a wave-cut cliff or else passes down to tide level and merges with the modern beach.

Recent terrace.—The lowest or Recent terrace is almost entirely confined to the submerged portion of the Coastal Plain. It is in process of formation in the large estuarine streams and in Chesapeake Bay and is continuous with the submarine portion of the Coastal Plain previously described. Wave action and currents are furnishing materials that are being deposited along the margin of the present shores. Parts of this terrace are submerged beneath many feet of water while other portions are only submerged during times of high tide. These latter areas constitute the tidewater marshes which are so well developed along the short estuaries on either side of Chesapeake Bay and occasionally from large areas several square miles in extent along the larger estuaries many miles distant from the Bay. These marsh areas are constantly being built up by the annual accumulations of vegetable debris and also receive mud deposits during seasons of flood. Other portions of the Recent terrace receive the sediments brought down by the streams and also in places the accumulation of oyster shells. Could the Recent terrace be exposed, there is no reason to believe that it would appear essentially unlike that of the Talbot. It would be a monotonously flat plain with gentle slopes toward the channels of the present estuaries and separated in many places from the Talbot by a low escarpment.

SAND DUNES.

In various places both on the eastern and western shores of the Chesapeake Bay there are accumulations of wind-blown sand of recent origin. These are most abundant where the surface soils are composed of loose fine sand but they also occur along the ocean border where they have been built up from beach sand. Most of these sand dunes are low banks of sand, seldom more than 10 feet in height and arranged in long windrows at right angles to the usual trend of wind movement. In general the lee side of a sand dune is steeper than the windward side. Many observations of the low dunes on the Eastern Shore show them to have a general northeast and southwest direction, those some miles from the ocean front having the steeper side to the southeast, indicating that the northwest winds of winter the much more influential in their formation than are the prevailing southwesterly winds of the summer season.

The largest dunes of the Virginia Coastal Plain are the beach dunes along the ocean and bay shores in the vicinity of Cape Henry. These parallel the shore for a distance of several miles and are composed of the beach sand blown inward by landward-moving winds. The dunes at Cape Henry reach an elevation of 70 feet. The ocean slopes are very gentle while the landward slopes are steep. These dunes are advancing landward and are now encroaching upon a forest, some of the trees of which have already been buried. The movement, however, is a very slow one as the present condition of the dunes is not very different than when described by B. H. Latrobe[a] in 1799.

DRAINAGE.

An almost complete surface drainage system has been developed in the Virginia Coastal Plain although the topography is comparatively recent. There are a few natural fresh-water lakes or ponds while fresh-water marshes are almost entirely confined to the borders of the sluggish streams. The Dismal Swamp and Lake Drummond are the notable exceptions, yet they are not the only ones, for in some places there occur over the higher-lying divides small undrained areas in which the surface water collects during the rainy season to form small ponds or swamps which are desiccated during the summer months. Usually, however, the surface soil and subsoil are so porous that underground drainage is effected when the surface drainage system is incomplete. It is thus that considerable areas to the southeast of Norfolk are drained.

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[a] Trans. Amer. Philos. Soc., 1799, Vol. iv. pp. 439-444.

The upper and lower courses of those streams whose sources are in the Piedmont Plateau but which cross the Coastal Plain are in striking contrast. In the hard crystalline rocks they have cut narrow steep-sided valleys and their channels are frequently filled with great boulders producing falls and rapids, while in the loose sediments of the Coastal Plain the valleys are wide and open, the streams frequently bordered by extensive flood plains with no obstacles to disturb the quiet sluggish flow of the low-gradient streams. Within the Piedmont Plateau and at its margin the large as well as the small streams furnish considerable water power, but in the Coastal Plain all the water power is furnished by the small tributary streams.

Within the Coastal Plain the streams have series of branches formed at approximately right angles to the next larger stream and producing a stream system somewhat similar to the branchings of a tree and therefore known as dendritic.

Stream courses.—The drainage of the Virginia Coastal Plain is simple in that neither the geological structure of the region nor the materials through which the streams have cut their valleys have had much influence upon the present stream courses. The initial slopes of the region have determined the direction of the streams, and as the general slope is toward the east or southeast all of the leading streams flow in that direction. In the vicinity of the "fall-line," however, many of them are deflected sharply to the right and flow almost due south for a distance of from 5 to 30 miles before finally cutting across the Coastal Plain in their direct course to Chesapeake Bay. It appears as if the superimposed streams of the Piedmont Plateau, after having maintained their straight courses in the hard crystalline rocks had encountered serious obstacles in the great deposits of unconsolidated materials in the Coastal Plain and had found an easier passage southward. It has been claimed by some investigators that the "fall-line" is a line of fracture and faulting and that the stream courses have been affected in consequence. The few small faults which have been observed in the overlying Coastal Plain deposits along this line and the greater slope of the formations suggest earth movements of greater magnitude here than elsewhere and these movements may have influenced the present position of the streams. It seems more probable, however, that the main cause is due to the relative ease with which the basal Coastal Plain deposits are eroded in comparison with the overlying beds. Notwithstanding the fact that with local exceptions all of the Coastal Plain deposits are unconsolidated, some are much looser and are removed by erosion much more readily. The beds of the Potomac group which outcrop in a narrow belt along the "fall-line" seem to resist stream erosion less than any of the other Coastal Plain formations. As a result the streams on entering the Coastal Plain province follow the outcrop of these beds for several miles. The best exposures of the Potomac beds are found along the Potomac, Rappahannock, North Anna, and James rivers in that portion of their courses where they flow in a southerly direction. The same conditions appear on the Appomattox River below Petersburg and in the Nottoway River in Sussex County except that these streams flow northward on the same beds, possibly due to an initial northerly slope in this portion of the Coastal Plain area. The Chickahominy agrees with the streams first mentioned above in flowing in a southerly course for several miles on reaching the Coastal Plain. Thus far the Potomac beds have not been observed along this part of the Chickahominy, but it is not improbable that they are there present but concealed from view by the more recent deposits which fill the valley.

Tide-water estuaries.—The most prominent features of the drainage of Virginia are the broad tidal estuaries which penetrate the State to the "fall-line" and divide the Coastal Plain region into a series of long, narrow peninsulas. These deep tidal streams have always contributed to the natural wealth of the State through the water products—oysters, crabs, and fish—which they have yielded in such great quantities, and also through the easy transportation which they have afforded for the products both of land and sea. When water transportation was practically the only means of conveyance the importance of these navigable streams was much greater than at present and for that reason tide-water Virginia was first brought under cultivation and during the 17th and 18th centuries was the leading section of the State. Foremost in importance among these bodies of water is Chesapeake Bay, while tributary to it are the long estuaries of the Potomac, Rappahannock, and James, between 150 and 200 miles in length and the shorter ones of the York, Wicomico, Piankatank, and Nansemond rivers and Mobjack Bay, besides hundreds of others of lesser importance. These all represent ancient valleys cut by streams when the country stood at a higher level than at present and which have been converted into their present condition by a depression of the country which permitted the waters of the sea to enter their valleys. In most of these estuaries the position of the former streams can be determined by the deeper channels but in some cases these have been obliterated by the deposits which have been laid down in them since their submergence. As little erosion takes place below tide level, it is possible to gain some idea of the amount of subsidence which has given rise to the present estuaries from the depths of the deepest portions of the channels. The greatest depths of the lower Chesapeake Bay are about 150 feet in the vicinity of Cape Charles City. Thus we feel confident that when the depressions of the estuaries now filled with the tidal waters were excavated, the country must have been at least 150 feet higher than at present and probably much higher since the old channel has been traced eastward of the capes in water of considerably greater depth.

The water in the lower portions of all these estuaries is almost as saline as the sea water but in ascending the streams the water becomes brackish and near the head of tide is essentially fresh. The terms river and creek as applied to these estuaries seem to be misnomers since throughout most of their courses the upward-moving tidal flood-current is almost as pronounced as the downward current which is a combination of the normal flow of the stream and the ebb tide. A difference is noted, however, as one ascends the streams in the relative duration of flood and ebb tide. For example, at the mouth of the Rappahannock River the mean duration of flood tide is 5 hours and 50 minutes and of ebb tide 6 hours and 35 minutes while at Fredericksburg in the upper part of the estuary the current moves down stream almost all the time.

The slow currents in the estuaries are not strong enough to transport the materials brought in by the side tributaries and as a result the estuaries are being rapidly filled. Every heavy rain causes an immense amount of mud to be carried down by the side streams, nearly all of which is dropped before the water passes into the ocean. Sometimes for weeks at a time the water in the Potomac, Rappahannock, and James rivers will have a distinctly muddy color because of the great quantity of fine particles held in suspension, a large part of which is deposited before the waters enter Chesapeake Bay. In the early days many of the streams were navigable many miles above the points where vessels are now able to go, while in other streams the channels can only be kept open by dredging. The width of the estuaries is also decreasing due to the encroachment of the marsh areas which so commonly border these streams.

Marshes or terraces do not everywhere border the estuaries, for in many places there are steep, almost vertical bluffs of considerable height which afford excellent exposures of the underlying rocks. These are formed where the meandering streams have cut away the lower-lying terraces and opposite them are almost invariably extensive marsh areas. In Westmoreland County the Nomini Cliffs, which extend for several miles along the Potomac River and reach a maximum elevation of 200 feet, are the highest bluffs in the

Coastal Plain of Virginia and probably the highest in the entire Atlantic Coastal Plain province. Although somewhat lower the cliffs at Carters Wharf on the Rappahannock River, at Mt. Folly and Yorktown on the York River, at Drewrys Bluff, Howlett House and Kings Mill on the James River, and at Point of Rocks on the Appomattox River are equally picturesque.

Minor streams.—Entering the head of almost every estuary and flowing into them from the side are tributary streams of varying lengths which have not yet cut down to tide and which have sufficient fall to furnish considerable water power. Hundreds of these, all through the region, have been dammed and used to generate the motive power for grist and saw mills. Not infrequently these streams have very deep, steep-sided valleys and where they are numerous the country is decidedly rugged. On the Potomac River side of King George County there is such a region.

A marked peculiarity is noticeable in the relative lengths of these minor streams draining opposite sides of the peninsulas. On the Northern Neck, the region between the Potomac and Rappahannock rivers, the divide lies very close to the Potomac River and as a result the streams flowing into the Potomac are short, swift streams with precipitous valleys, while those flowing into the Rappahannock are longer, descend from the upland in easier stages, and have more open valleys. The same features are observed in the peninsulas between the Rappahannock and York rivers and between the York and James rivers, while more than three-fourths of the region lying to the south of the James River is drained southward into the Chowan River of North Carolina. The unsymmetrical location of the divides snows that the southward-flowing streams with their greater drainage areas have been enabled to cut back into the divides more rapidly than have the streams flowing to the north. This condition of affairs has probably been brought about by a slight tilting of the whole region to the southward or southwestward although an attempt has been made to find an explanation foı this phenomenon from the effects of the earth's rotation.

The Dismal Swamp.—A discussion of the drainage of Coastal Plain Virginia should include a description of the Dismal Swamp. The statement which follows is taken from the Norfolk folio, U. S. Geological Survey, by N. H. Darton, who has made an exhaustive study of the district.

"The larger portion of this great fresh-water morass lies in the Norfolk quadrangle. It is an area of moderately elevated, nearly level land with such imperfect drainage that it remains constantly inundated to a slight depth. The outlines of the swamp area are irregular and usually the limits are not well defined, the position of the edges of the wet portion varying with the rainfall and the presence of the swamp flora. Some marginal areas which are cleared have ceased to be swampy except in wet weather. The swamp is heavily wooded and contains extensive canebrakes. The swamp, which slopes gradually upward to the southwest, varies in altitude from 12 to 22 feet above mean tide level. Near its center there is a picturesque body of open water, known as Lake Drummond. This lake is nearly circular in outline, about 2¾ miles in diameter, and until recently its surface was slightly over 22 feet above mean tide level, being the highest portion of the swamp. At one time its depth was about 15 feet, due in part to the damming of the swamp by banks of canals. Now, owing to the deepening of the canal feeder, the lake is only about 6 feet deep and the surface correspondingly lower than it is known to have ever been before. Its floor is largely covered with white sand. The lake water is light brown in color, due to a considerable amount of finely divided vegetal matter in suspension. It is thought to be perfectly wholesome, and as it is famous for its keeping properties it has been used extensively for supplying ships for long voyages. The lake is surrounded by woods, and at some points cypress trees are found growing in the water. The depth of the water decreases rapidly in the woods adjoining the lake, and over the swamp area in general it is rarely more than 1½ feet, except possibly in very wet weather. The average depth is from 1 to 3 inches, but in many portions the average depth is from 6 to 8 inches. In very dry seasons the amount diminishes all over the swamp area.

"Some marginal portions of the swamp have been drained for farming land, for which the soil is admirably adapted. The swamp area known as the Green Sea was originally a portion of the main swamp, but the Dismal Swamp Canal, which traverses the eastern portion of the area from north to south, has in a measure drained the intervening region. This canal sustains the water level and the resulting swamp conditions to the west, but has reclaimed from inundation a zone of considerable width to the east, an area which is further drained by the branch ditch known as the Herring Canal. The swamp flora is characterized by the occurrence of bald cypress, juniper, black gum, and extensive canebrakes.

"The swamps lie in shallow basins in the surface of the general terrace of the Norfolk region. The basins are now filled to the general level of the surrounding country with vegetal accumulations, which have a maximum thickness of about 20 feet. In recent excavations for a gate on the feeder about half a mile east of Lake Drummond there were exposed 10 feet of peat filled with roots and tree trunks, lying on 8 feet of clear peat which merged with the overlying beds, and this in turn was underlain by fossiliferous sand of late Neocene age. The thickness of the swamp deposits decreases toward the periphery of the present swamp area, but so few excavations have been made along the border zone that the conditions of thinning are not known. The upper beds of peaty materials merge gradually into the sands of the adjoining area, so that no boundary line can be given.

"The basin of the Dismal Swamp owes its origin to an extensive depression in the surface of the Columbia formation. At first this hollow was probably a slough in the terrace surface. When the Columbia formation was deposited James River had essentially its present course, but emptied into open water some distance northwest of the swamp. Its main current appears to have built a bar or broad delta which extended eastward and thus built up the terrace plain that lies east and southeast of Norfolk. Between this delta and the steep slope at the edge of the highlands which lie a short distance west of the Norfolk quadrangle there remained an area of lowland, a slough which was not built up appreciably by the Columbia deposits. When the delta was uplifted it became a high terrace with good drainage conditions, while the slough became a swamp filled with luxuriant vegetation, and it has so continued ever since. At first, when the vegetation was young, relatively fine-grained peat accumulated, but as the forest grew older, roots and trunks were intermixed with the finer materials, and finally the depression was filled up to the general level of the country by these accumulations. It is now so remote from the larger drainage ways and so choked with canebrakes that its drainage is still very imperfect and the swamp conditions continue over nearly all the original basin area. Lake Drummond is no doubt the remaining portion of an original center pond, probably greatly encroached on by the forests and canebrakes. It is probable also that during some periods the lake was dry for a short time. Its bottom has been raised somewhat by vegetal accumulations, but probably its water level has just about kept pace with the general rise of the swamp surface."

GEOLOGY OF THE VIRGINIA COASTAL PLAIN

INTRODUCTORY.

The great body of deposits forming the Coastal Plain of Virginia has been laid down along the border of the Piedmont Plateau on the floor of crystalline rocks of which that district is composed. These deposits are very thin in the vicinity of the "fall-line," but the accumulation of materials gradually increases to the eastward until the thickness reaches several thousand feet. At Fortress Monroe a government well penetrates the entire thickness of the Coastal Plain, reaching crystalline rocks at a depth of 2246 feet. At first estuarine in character, these deposits were later of marine origin and continued to be chiefly such until the later geological epochs when the marginal deposits of the Pleistocene were laid down in the inclosed bays and estuaries of the dissected Coastal Plain.

Although composed of a succession of formations which represent nearly every period from the Cretaceous to the Recent, the Coastal Plain deposits do not succeed each other in a conformable series, nor do they possess the same strikes and dips. Differential movements took place that materially affected the attitude of the beds by which, in certain sections, the landward exposures of whole formations that appear in adjacent regions have been eliminated. Thus the Upper Cretaceous deposits, so well exhibited in Maryland, are gradually transgressed by the Eocene southward, shutting out the former throughout the entire area of outcrop in Virginia, although recognized in the deep-well borings at Fairport and Fortress Monroe.

In general the beds strike from north to south although some variation occurs. The strata have a general easterly dip, which changes from 50 feet in the mile in the lowest formations, about the slope of the crystalline floor on which the deposits rest to less than 5 feet in the mile in the highest deposits. With this relatively low dip the beds generally appear horizontal in any particular section and may be actually so locally, so that measurements must be extended over a wide area before the average dip of any particular formation can be determined.

Formations represented in the Virginia Coastal Plain.

Age	Formation	Group
CENOZOIC		
Quaternary		
Recent		
Pleistocene	Talbot Wicomico Sunderland	Columbia group
Tertiary		
Pliocene (?)	Lafayette	
Miocene	Yorktown St. Mary's Calvert	Chesapeake group
Eocene	Nanjemoy Aquia	Pamunkey group
MESOZOIC		
Cretaceous		
Upper Cretaceous		
Lower Cretaceous	Patapsco Patuxent	Potomac group

MESOZOIC

CRETACEOUS.

The Cretaceous deposits of Virginia constitute part of the basal sediments of the Coastal Plain and overlie the crystalline rocks of the Piedmont Plateau along its eastern margin. Well borings near the eastern border of the Coastal Plain have never penetrated deposits of earlier age overlying the floor of crystalline rocks although they may exist still farther to the eastward beneath the submarine portion of the Coastal Plain. The Virginia deposits of this age are confined entirely to the Lower Cretaceous along the line of outcrop, although Upper Cretaceous deposits have been recognized in the deeper well borings. Where exposed at the surface these Lower Cretaceous sediments have been transgressed by the Tertiary formations, either Eocene or Miocene deposits overlying them uncomformably, as the case may be, although in the absence of the latter the Quaternary deposits often rest immediately on the Cretaceous beds.

LOWER CRETACEOUS.

BY

EDWARD W. BERRY.

THE POTOMAC GROUP.

Along the eastern border of the Piedmont Plateau, lying for the most part directly on the flanks of its ancient crystallines and constituting the basal element of the Atlantic Coastal Plain, is a series of mostly unconsolidated, arenaceous, arkosic, argillaceous and often ferruginous or lignitic✓ sediments of highly varied character. Their outcrop constitutes a relatively narrow belt, extending from Pennsylvania to Alabama and ranges from a few to 20 miles in width, its landward boundary lying somewhat westward of the "fall-line". The thickness of the beds at the point where they pass beneath tide, ranges from 100 to 1,000 feet, dependent largely upon whether the full sequence of formations is present or not, although the formations themselves are very variable in thickness.

The flora of these deposits is a highly varied one consisting of equiseta, numerous ferns, cycads and conifers, a few monocotyledons, and a considerable variety of dicotyledons especially in the upper beds. The known fauna is a meagre one including a few pelecypods and gastropods of brackish water or estuarine habitat, a single fish and a considerable number of reptiles, especially dinosaurs. From the Arundel formation in the Maryland area both gigantic and diminutive forms of this order have been collected as well as the remains of stegosaurs and crocodilians.

That the Potomac sediments were laid down as terrestrial, lacustrine and fluviatile sediments, combined with contemporaneous deposits in shallow water along the Lower Cretaceous shore-line, is indicated by the absence of any strictly marine fossils and sediments, and by the presence of a few estuarine species of shells, and by the abundance of delicate plant remains often but slightly if at all triturated. The fossil wood is also frequently silicified or lignitized without having suffered much from decay. The coarseness of a large proportion of the materials, the frequency of marked current bedding, and the presence of a large amount of coarse gravel or even cobbles, effectually confirms the littoral and estuarine conditions under which the Potomac formations were deposited.

The deposits constituting the Potomac group were at first thought to constitute a single formation and in 1886 Dr. W J McGee[a] applied the name Potomac to them because of their extensive development in the Potomac River basin near Washington. Later investigations in Maryland have clearly demonstrated the fact that these deposits do not constitute a single formational unit, and in 1897 Clark and Bibbins[b] proposed a fourfold classification which has now come to be generally accepted. The formational names in order from the oldest to the youngest were the Patuxent, the Arundel, the Patapsco, and the Raritan. More recently the uppermost of these formations, the Raritan, has been referred to the Upper Cretaceous.

The Patuxent is the most constant from Maryland southward. The Arundel attains a considerable development in central Maryland, but disappears to the northward in northeastern Maryland and to the southward in southern Maryland. The Patapsco is largely developed from Delaware to the vicinity of Fredericksburg, Virginia, where it disappears. The known Raritan extends from the islands off the southern coast of New England to southern Maryland where it is transgressed by much later deposits of Tertiary age.

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[a] Report of Health Officer, D. C., 1884-5 (1886), p. 20.

[b] Jour. of Geol., vol. v, pp. 479-506.

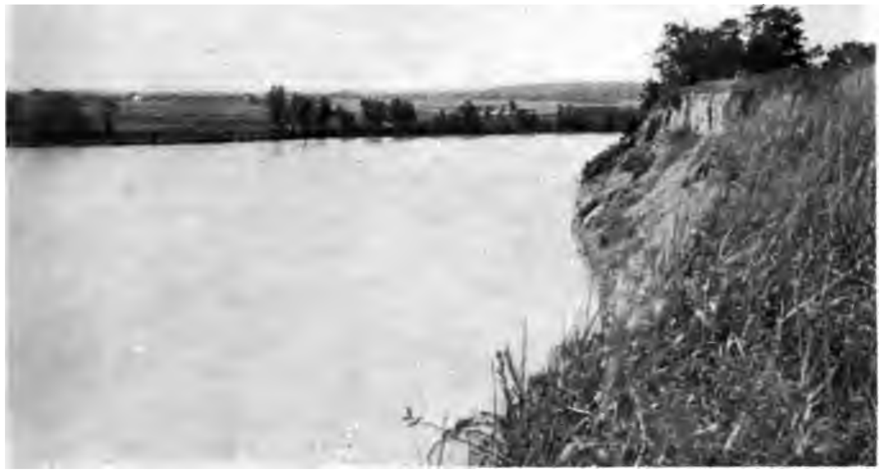


Fig. 1.—Bluff at Dutch Gap, James River, looking upstream. Showing Patuxent formation overlain by Pleistocene deposits.

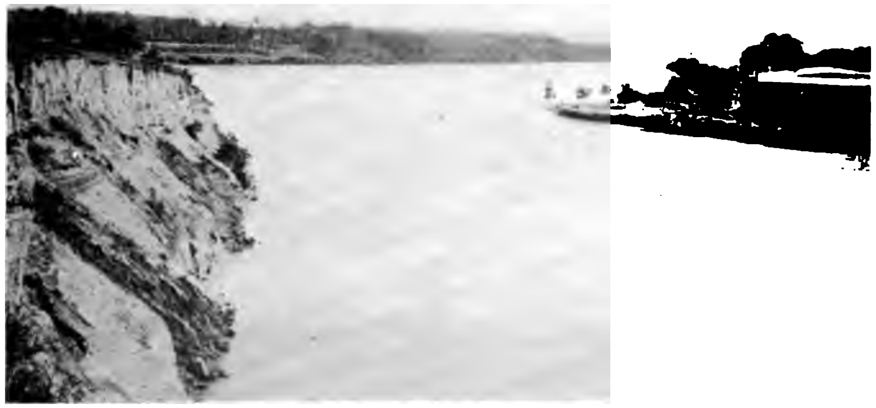


Fig. 2.—Bluff at Dutch Gap, James River, looking downstream. Showing Patuxent formation overlain by Pleistocene deposits.

PATUXENT FORMATION OVERLAIN BY PLEISTOCENE DEPOSITS.

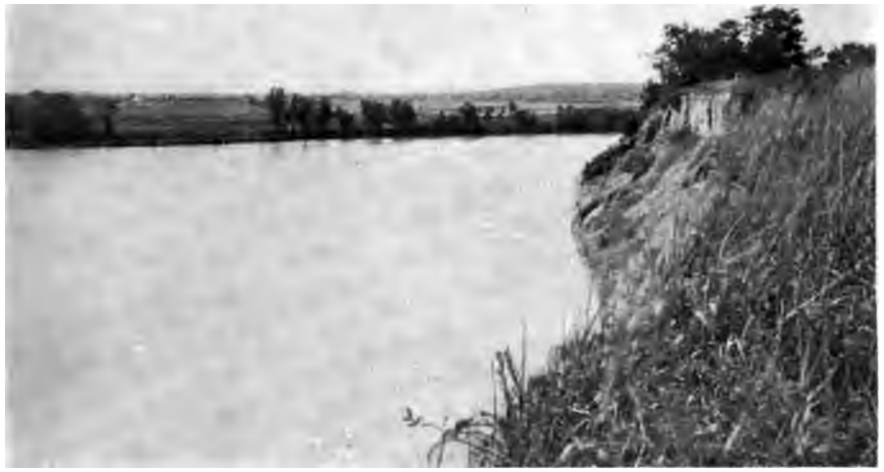
The total exposed thickness of the Potomac formations in Virginia in the region of their outcrop is about 500 feet. The formations thicken down the dip to the eastward, and in all probability the Raritan also, although undifferentiated, is present beneath the Tertiary cover. At Fortress Monroe the combined thickness of the Potomac formations, penetrated in the new government well, is about 1,300 feet.

The Patuxent Formation.

Name.—The Patuxent formation, so called from the Patuxent River, Maryland, where the deposits are well exposed, constitutes the basal portion of the Potomac group.

Stratigraphic relations.—The Patuxent beds rest throughout most of their area, with marked unconformity, upon the crystallines of the Piedmont and the contact is observable at numerous outcrops. In a limited area around Doswell the Patuxent rests upon the Triassic. In most of the region from Alexandria to Fredericksburg the Patapsco unconformably overlies it. South of Fredericksburg either the Eocene or the Miocene deposits directly overlie the Patuxent. The Lafayette and Pleistocene deposits also frequently cover the Patuxent outcrops along the larger valleys.

Lithologic character.—The materials composing the Patuxent are variable, the formation frequently changing its lithologic characters rapidly in both vertical and horizontal directions. The deposits consist chiefly of light-colored sands, sometimes almost entirely made up of pure quartz grains, but usually containing a large amount of kaolinized feldspar (arkose) resulting from the decomposition of granitic rocks in the region to the westward. Mica flakes derived from the same source are very abundant at certain localities as are also greenish clays which derive their color from the chloritic schists of the Piedmont. Above Dutch Gap along the James River certain beds composed of quartz, mica, and kaolin so closely resemble the residual materials resulting from the decay of the granitic rocks that the planes of stratification are almost the only clue to their real origin. The quartz grains are generally quite well rounded, although in some places, as in the locality above cited, they are decidedly angular. The sands locally become indurated, sometimes so firmly as to be of value as a building stone. Before the day of railroads these indurated layers were quarried in a number of places. At Aquia Creek the United States government in the early part of the last century quarried a sandstone from this formation for the construction of the White House, the old por-



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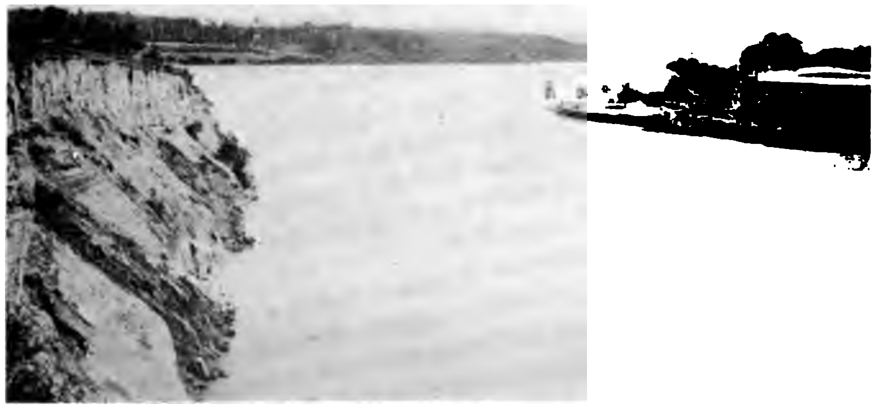

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Cobbles and boulders are not uncommon in the Patuxent deposits. Sometimes they form distinct beds while at other times they occur irregularly distributed throughout strata of finer materials. At the base of the Howlett House bluff on the James River opposite Farrar Island there is a conglomerate bed 30 feet in thickness of large and small cobbles and pebbles in a matrix of coarse arkosic sand, the whole locally indurated.

Although sands predominate in the Patuxent formation, clays are not altogether absent. The beds of sand occasionally pass into clay deposits while in other places the sand and clay beds are interstratified. The sandy clays frequently contain great quantities of lignitic material. In cutting the Dutch Gap canal on the James River a log of lignite about 60 feet in length and 10 inches in diameter is said to have been taken out. The Patuxent clays are seldom highly colored, so that they can generally be very readily distinguished from the variegated clays of the Patapsco formation. In the vicinity of Dutch Gap there are irregular masses of dark-colored clay embedded in the sandy strata. Some of these are several feet in diameter and are decidedly angular, showing that they were only transported a short distance. Many fine plant impressions frequently occur in them. The sands are almost invariably cross-bedded.

Strike, dip, and thickness.—The general strike of the Patuxent formation throughout Virginia is almost due north and south. The dip is to the east at the rate of nearly 50 feet to the mile in the region of the "fall-line", while farther to the eastward it decreases to about 30 feet to the mile. To the eastward of the line where the deposits disappear beneath the later sediments the dip has not been determined, except that at Fortress Monroe, 75 miles to the eastward the base of the Potomac deposits is reached at a depth of 2,246 feet indicating a still more gentle dip over this area. The floor of crystalline rocks upon which the Patuxent formation rests is very irregular so that the thickness of the deposits is extremely variable. This is well shown along the James River where just below Richmond the Patuxent deposits extend to tide, while about a mile and a half above Dutch Gap the crystalline rocks reappear along a small stream which empties into the James River. The Patuxent beds where they have been differentiated at the outcrop have a thickness of from 250 to 300 feet.

Paleontologic character.—Although the Patuxent deposits are in general unfossiliferous because of their coarse character, nevertheless a large flora has been collected from clay balls and lenses and the more argillaceous sands. This flora has been elaborated by Professors Ward and Fontaine in various publications of the U. S. Geological Survey[a] and is undergoing revision by the writer at the present time.

It includes a large element made up of survivors from the older Mesozoic and is rich in species and individuals referred to the fern genera *Cladophlebis* and *Onychiopsis*. A variety of cycad fronds testify to the abundance of this type of plant and is emphazised by the presence of numerous silicified trunks in the Maryland area. Perhaps the most striking of the cycad remains are the splendid fronds referred to the genus *Dioonites* which are extremely abundant in the Dutch Gap region. Other forms of cycads present include species of *Podozamites, Zamiopsis, Nilsonia, Ctenis, Ctenophyllum,* most of which are confined to the older Potomac and do not occur in the Patapsco deposits although some of them occur in the Arundel formation in Maryland.

Among the conifers are species of *Baiera, Brachyphyllum, Sphenolepis, Frenelopsis, Nageiopsis, Arthrotaxopsis* and *Cephalotaxopsis,* representative of various subfamilies which in the modern flora are largely natives of other continents. Supposed Angiosperms, the most ancient known, are represented by the archaic genera *Rogersia, Proteaephyllum,* and *Ficophyllum,* which may well represent the foliage of some Lower Cretaceous member of the Gnetales and not angiospermous plants, a point not yet definitely settled.

Areal distribution.—The Patuxent formation has been recognized chiefly in the Chesapeake Bay drainage basin in Maryland and Virginia, although the Nottaway River exposures in southern Virginia are very probably referable to this formation.

In the Virginia area the Patuxent formation is found near the head of tide in the leading drainage basins lying directly upon the very uneven floor of crystalline rocks which constitute the eastern margin of the Piedmont Plateau. The outcrop is more or less continuous from Washington to the Rappahannock River at Fredericksburg. South of Fredericksburg exposures are seen only along the banks of the larger streams. In the vicinity of Doswell it outcrops along the North Anna River for a distance of several miles above the confluence with the South Anna River which unites with the former to form the Pamunkey. In the vicinity of Richmond the Patuxent is exposed almost continuously along the banks of the James River from the State capitol to Jones Neck a few miles above Bermuda Hundred, exhibiting a number of most excellent exposures, notably at Drewrys and Chaffins bluffs and in the vicinity of Dutch Gap. In the Petersburg region the Patuxent outcrops along the Appomattox River at intervals from that town to within a short distance of its junction with the James River at City Point. Numerous exposures are to be observed, notably at Point of Rocks. The most southerly exposures of the Patuxent in Virginia are found to a limited extent in the valley of the Nottoway River in western Sussex County, although these have not been seen by the writer. No other river in southern Virginia has succeeded in cutting a channel to the Potomac surface, although it may be noted that unmistakably reworked Patuxent materials are abundant in the Pleistocene in the vicinity of Emporia. South of the Virginia line the Patuxent formation extends across North Carolina, broadening out to a remarkable extent in the upper Cape Fear basin around Fayetteville.

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[a] Monograph XV, 1889, 4°, XIV, 377 pp., 180 pls. Fifteenth Ann. Report, 1893-94. Monograph XLVIII, 1906.

The Arundel Formation.

(NOT RECOGNIZED IN VIRGINIA.)

The Patuxent formation is succeeded in the Maryland area by a series of stratified clay beds, fine in texture and brown in color, carrying a large amount of carbonaceous matter and considerable deposits of iron ore which were used extensively in colonial days. These beds, long known as the "iron ore clays," contain a varied flora scarcely distinguishable from that of the Patuxent formation, and a considerable, chiefly dinosaurian, fauna which finds its counterpart in the Morrison beds of the West and the Wealden of Europe.

The Arundel deposits are thought to represent discontinuous swamp and lagoon accumulations in warped valleys of post-Patuxent time and are therefore unconformable upon the older beds. They owe their iron to the fact that their sediments were largely derived from the decay of gabbro and other iron-rich crystallines lying immediately to the westward of the

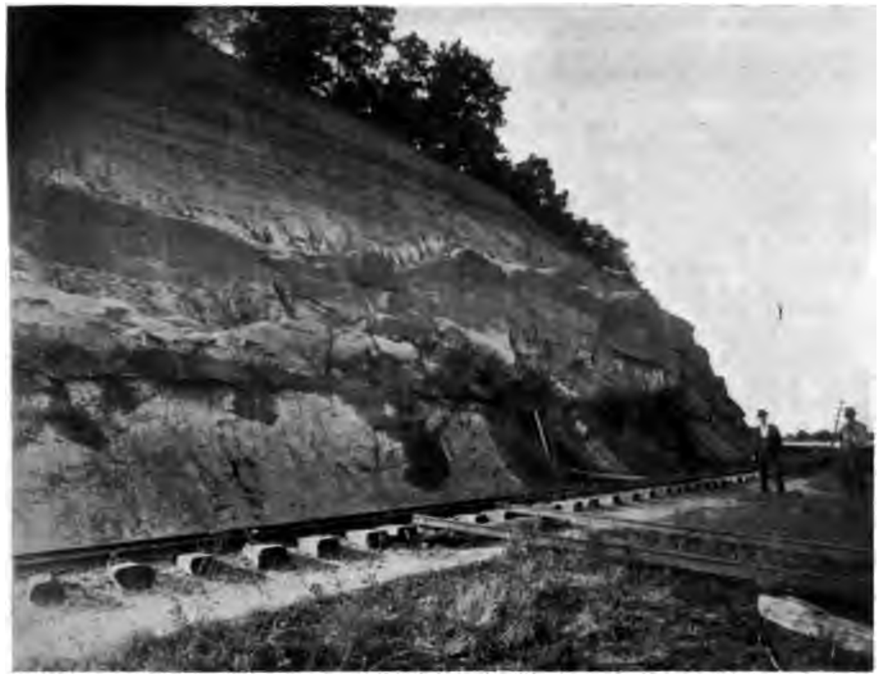

Fig. 1.—Cut on R. F. & P. R. R. near Cockpit Point. Showing sandy beds of Patuxent formation.

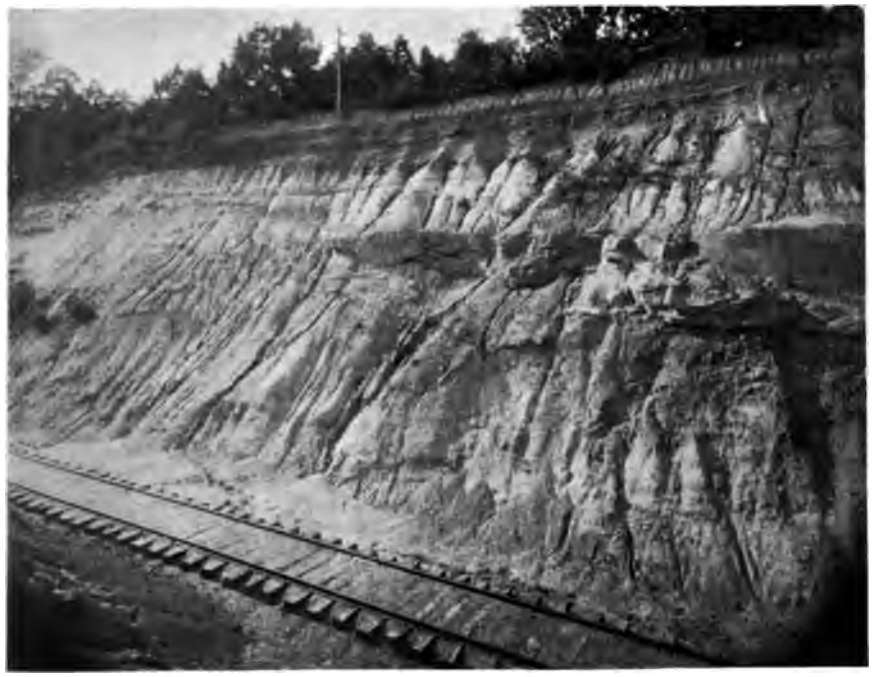

Fig. 2.—Cut on R. F. & P. R. R. near Cockpit Point. Showing sandy beds of Patuxent formation.

SANDY BEDS OF PATUXENT FORMATION.

area of their most extensive development, while in the Virginia area the source of the Potomac sediments were the granitic and gneissoid rocks which there constitute the eastern Piedmont.

The Arundel is typically developed in the area between Baltimore and Washington in Anne Arundel and Prince George's counties, Maryland. It is also present in Baltimore City and in Baltimore and Harford counties but has not been recognized farther to the northeast in Cecil County, Maryland, or to the southwest in the valley of the Potomac River.

The Patapsco Formation.

Name.—The Patapsco formation receives its name from the Patapsco River, Maryland, in the valley of which excellent exposures of these beds are found.

Stratigraphic relations.—In Maryland the deposits of the Patapsco formation rest unconformably upon the Arundel where it is present and in other places upon the Patuxent formation or the crystallines of the Piedmont Plateau. Throughout their area of outcrop in Virginia the Patapsco deposits rest with marked unconformity upon the Patuxent. In the stream valleys the deposits frequently have a covering of Pleistocene materials while Lafayette gravels, sands, and loam often cap it when it rises to the height of the stream divides. It disappears from view along the eastern margin of its outcrop beneath the Aquia formation of the Eocene, which is also found capping it in the higher hills and may be seen in several places in Stafford County about Aquia, Accokeek, and Potomac creeks.

The Patapsco was greatly eroded in pre-Eocene times, its upper surface being extremely uneven, this undulating contact, emphasized by the marine beds of the overlying Aquia formation, being one of the sharpest lines in the whole Coastal Plain.

From the record of the deep wells near the mouth of the James River, notably at Fortress Monroe, it is believed that the Upper Cretaceous deposits so extensively developed in Maryland and New Jersey intervene between the Patapsco and Aquia formations.

Lithologic character.—The Patapsco, like the Patuxent formation consists of very variable materials—clays, sands, gravels, and conglomerates. The deposits, however, are more uniform and finer than those of the Patuxent, consisting chiefly of highly colored and variegated clays, which grade over into lighter colored sandy clays, while sandy bands of coarser materials are at times interstratified. The sands frequently contain much decomposed feldspar and like those of the Patuxent are often cross-bedded, and occasionally lithified. The Virginia deposits are in general much less highly colored than those of the Maryland region, a feature due to the absence of iron rich crystallines in the area from which their sediments were derived. The clays, like those of the Patuxent in Virginia are frequently greenish when unweathered, due to the presence of chlorite derived from the chloritic schists of the Piedmont.

Strike, dip and thickness —The strike of the Patapsco beds in Virginia is almost due north and south and the dip is about 30 feet to the mile to the eastward. The total thickness in the region of outcrop is about 150 feet, but this increases to the eastward beneath the overlying Tertiary deposits.

Paleontologic character.—The Patapsco deposits have yielded a few specimens of undeterminable unios and an extensive flora made up of ferns, cycads, conifers, monocotyledons and dicotyledons. The ferns, cycads, and conifers represent the dwindling remnants of the Patuxent and Arundel flora, quite a number of the older Potomac species continuing through the Patapsco as for example *Nageiopsis angustifolia* Font., and various species of *Cladophlebis*, *Onychiopsis, Sequoia,* and *Sphenolepis.* In other cases the same genera are represented by distinct species at the two horizons as in the genus *Acrostichopteris.*

A species of *Pinus* represented by seeds, cone-scales, and cones is one of the characteristic forms of this formation as are also the cone-scales referred to *Araucaria aquiensis* Font. The twigs of *Widdringtonites ramosus* (Font.) Berry are also a rather constant feature of the Patapsco fossiliferous outcrops and furnish a point of contact with *Widdringtonites Reichii* (Ett) Heer of the Upper Cretaceous. Other characteristic Patapsco forms are the various species of the dicotyledonous genus *Sapindopsis* and the fern *Knowltonella Maxoni* Berry. The marked distinctness of the Patapsco flora, however, rests mainly upon the great increase and modernization of the dicotyledons which foreshadow those of the Raritan.

The more characteristic of these are various species of *Sapindopsis*, *Celastrophyllum*. *Sassafras, Sterculia, Cissites, Aralæphyllum, Populophyllum*, etc.

Areal distribution.—The Patapsco formation has been recognized in isolated remnants in Pennsylvania and Delaware, it outcrops in a broad belt across Maryland, and continues southward into Virginia through eastern Fairfax, Prince William, and Stafford counties to the vicinity of Fredericksburg. It is most extensively developed in the valley of the Potomac River, appearing in numberless bluffs from Washington to where it finally disappears beneath the Eocene in the vicinity of Aquia Creek,

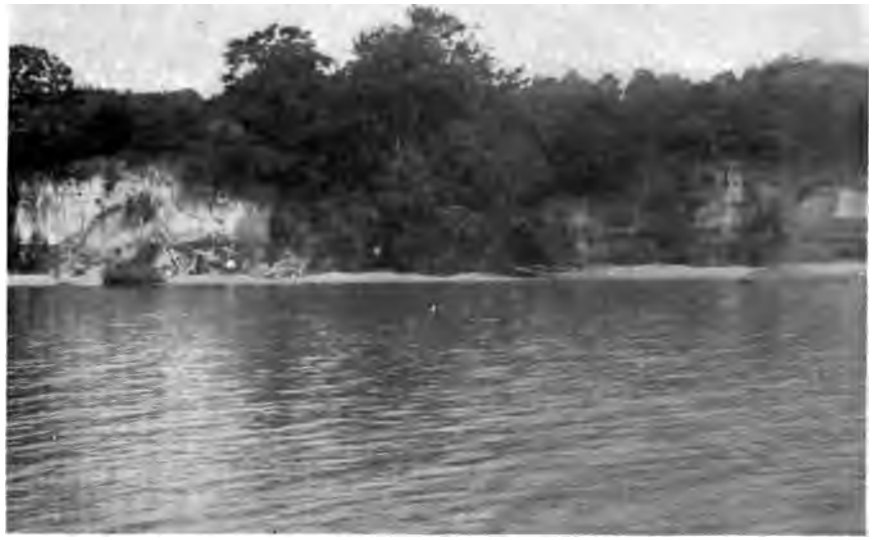

Fig. 1.—Bluffs above Widewater on Potomac River. Showing Patapsco formation overlain by Pleistocene deposits.

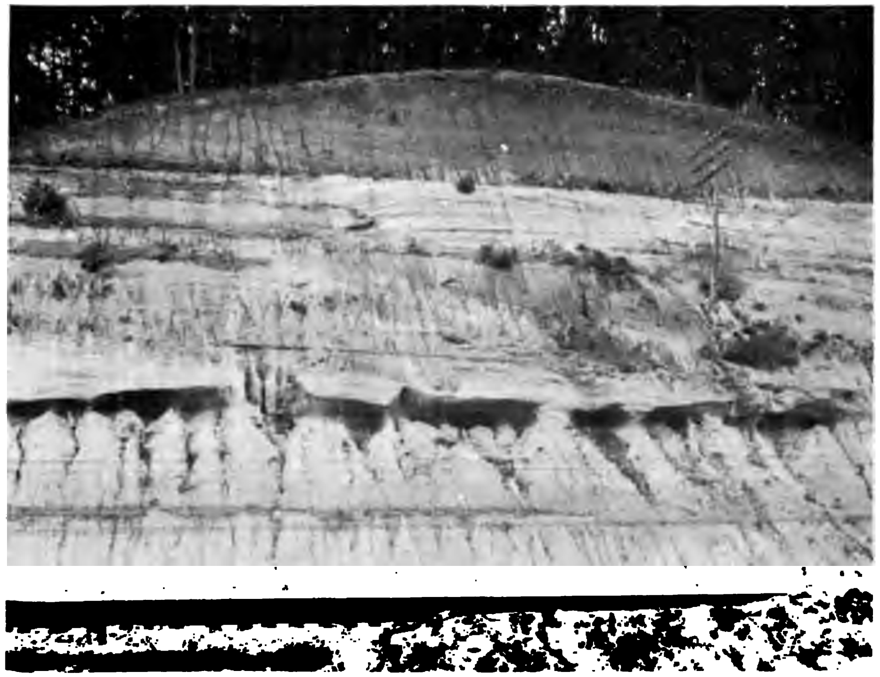

Fig. 2.—Cut on the R. F. & P. R. R. south of Aquia Creek. Showing Patapsco formation overlain by Aquia formation.

PATAPSCO FORMATION.

Virginia. The Patapsco is found on Potomac Creek about a mile below the railroad crossing and on Aquia Creek, in the vicinity of the railroad bridge, and at tide on the Rappahannock River near the mouth of the Massaponax River. There are also numerous exposures and fossiliferous outcrops in the area around Brooke. A single exposure of positively determinable age is found in the valley of the James River at Deep Bottom 4 miles below Dutch Gap canal at the most eastern point where the Potomac deposits appear above tide. From these points it rises rapidly to the west along the sides of the valleys and forms the tops of the hills, except for the thin covering of Eocene, Lafayette, or Pleistocene materials which overlie it.

DETAILED SECTIONS.

POTOMAC RIVER SECTIONS.

The Potomac strata outcrop at intervals along the Virginia bank of the Potomac River from Alexandria almost to the mouth of Aquia Creek. The first locality worthy of mention is on the Mt. Vernon estate a short distance below the steamboat landing. This and other exposures in the immediate vicinity and up Doag Creek are very poor and much covered, but as they are very fossiliferous they merit some description. At several points along the base of this bluff 10-15 feet of Potomac materials are exposed. These consist of arkosic, irregularly-bedded, light sands, more or less indurated with thin layers of more argillaceous materials brownish or pinkish in color and carrying leaf impressions which are usually somewhat contorted. The materials are all of Patapsco age and the more important forms found include the following:

Acrostichopteris longipennis Font.
Antholites Gaudium-Rosae Ward
Aralia ? vernonensis Font.
Aristolochiaephyllum ? cellulare Ward
Casuarina Covillei Ward
Celastrophyllum Brittonianum Hollick
Celastrophyllum Hunteri Ward
Celastrophyllum ? saliciforme Ward
Cladophlebis rotundata Font.
Ephedrites ? vernonensis Font.
Nelumbites tenuinervis (Font.) Berry
Nelumbites virginiensis (Font.) Berry
Nageiopsis angustifolia Font.
Nageiopsis longifolia Font. ?
Onychipsis Goepperti (Schenk) Berry
Pinus vernonensis Ward
Populophyllum minutum Ward
Populophyllum reniforme Font.
Populus potomacensis Ward
Potamogetophyllum vernonense Font.
Sagittaria Victor-Masoni Ward
Dicksoniopsis vernonensis (Ward) Berry
Sphenolepis Sternbergianum (Dunk.) Schenk
Thyrsopteris grevillioides (Heer) Hollick
Sterculia elegans Font. ?
Thinnfeldia Fontainei Berry
Widdringtonites ramosus (Font.) Berry
Zamites tenuinervis Font.

The next locality is at White House bluff about 2 miles below Mt. Vernon where the following section is exposed at intervals along the bluff:

I. *Section at White House Bluff.*

			Feet
Pleistocene		Ferruginous sand and gravel...............	10-20
		Ferruginous sand with cobbles up to 12 inches in diameter	5
Lower Cretaceous.	Patapsco	Gray or buff incoherent sand with thin lenses of reddish clay..........................	15
		Pinkish or brownish sandy clay with tests of Estheria and leaf impressions including *Acrostichopteris longipennis* Font., *Araucarites aquiensis* Font., *Carpolithus brookensis* Font., *Celastrophyllum albaedomus* Ward, *Sapindopsis magnifolia* Font., *Sapindopsis variabilis* Font., *Dichotozamites cycadopsis* (Font.), *Sphenolepis sternbergiana* (Dunk.) Schenk and *Widdringtonites ramosus* (Font.) Berry	3-5
		Much cross-bedded and slightly arkosic coarse buff sand, somewhat argillaceous and with scattered pebbles and clay laminae........	20-25
		Indurated much cross-bedded and very arkosic gray sand with scattered pebbles..........	20-25
		Total..............................	73-95

On the south side of Gunston Cove opposite White House bluff the following section is exposed, the Potomac materials extending to the top of the bluff:

II. *Section of Gunston Cove Bluff.*

			Feet
Lower Cretaceous.	Patapsco	Massive buff or gray coarse sand............	20
		Gray incoherent irregularly-bedded sand alternating with thin lenses of brownish sandy clay carrying undeterminable plant remains	40
		Greenish sandy chloritic clay weathering to reddish and purplish mottled colors becoming sandy above	20
		Total..............................	80

The next exposure of any extent below Gunston Cove is that at Freestone Point, which, by combining the exposures along the river with those in the deep cut of the R. F. and P. R. R. at this point, give the following section:

III. *Section at Freestone Point.*

			Feet
Pleistocene		Light cross-bedded iron-stained sands with pebbles and clay pellets....................	0-20
Eocene.	Aquia (?)	Argillaceous greensand	4-8
Lower Cretaceous.	Patuxent	Gray cross-bedded coarse arkosic sand with indurated ledges and scattered pellets and lenses and balls of greenish argillaceous materials, very variable horizontally and vertically	40-50
		Gray indurated cross-bedded arkosic sand....	30
		Total..............................	74-108

IV. *Section at Cockpit Point.*

			Feet
Pleistocene		Iron-stained sandy loam with gravel at the base	15-20
Lower Cretaceous.	Patuxent	Buff cross-bedded sand with some lignite and a few clay balls, carrying leaf impressions in the more argillaceous layers. These include *Cladophlebis parva* Font., *Dioonites Buchianus* (Ett) Born., *Equisetum Burchardti* (Dunk.) Brongn., *Feistmantelia oblonga* Ward, *Nageiopsis zamioides* Font., *Nageiopsis longifolia* Font., *Podozamites* sp., *Scleropteris elliptica* Font., *Sequoia ambigua* Heer, *Sphenolepis Kurrianum* (Dunk.) Schenk, *Sphenolepis Sternbergiana* (Dunk.) *Onychiopsis Goepperti* (Schenk) Berry, etc....	18
		Greenish, massive, chloritic, sandy clay......	10
		Total..............................	43-48

This and the preceding are the only decisive exposures of Patuxent on the Potomac River and evidently owe their preservation to the resistant character of the Patuxent materials, which are firmly indurated, forming the well-known "freestone" formerly much quarried in this vicinity. The unconformable nature of the Patuxent-Patapsco contact is well shown, since about a mile south directly along the strike a characteristic Patapsco flora is found at a somewhat lower level.

V. *Section Dumfries Wharf just above Quantico Creek.*

			Feet
Pleistocene		Ferruginous sandy loam with gravel bed and boulders at the base	15
Lower Cretaceous.	Patapsco	Gray arkosic sand more or less indurated and cross-bedded below, with small lenses of sandy clay carrying leaf impressions including *Acrostichopteris longipennis* Font., *Brachyphyllum crassicaule* Font., *Sassafras* sp., *Sphenolepidis sternbergiana* (Dunk.) Schenk, *Zamites tenuinervis* Font., etc	6-10
		Total	21-25

VI. *Section just above Widewater, Virginia.*

			Feet
Pleistocene		Sandy loam with gravel base ....about	10
Lower Cretaceous.	Patapsco	Coarse, arkosic, cross-bedded, partially lithified, somewhat argillaceous sand	15-20
		Local unconformity with iron crusts. Chloritic sandy drab clay with leaf impressions including *Araucarites aquiensis* Font., *Sassafras sp.*, *Sapindopsis variabilis* Font., *Zamites tenuinervis* Font. etc., exposed to water	5-10
		Total	30-40

The foregoing exposure is continuous along the river, the lithology being variable. About one-quarter of a mile above the section just given, the same flora is found above the unconformity, showing that it is purely local in character.

VII. *Section one-quarter of a mile above last.*

			Feet
Pleistocene		Sandy loam with gravel	8-12
Lower Cretaceous.	Patapsco	Argillaceous sand with lenses of brownish sandy clay carrying leaf impressions including *Araucarites aquiensis* Font., *Brachyphyllum crassicaule* Font., *Celastrophyllum acutidens* Font., *Feistmantellia oblonga* Ward, *Onychiopsis psilotoides* (Stokes & Webb) Ward, *Pinus vernonensis* Ward, *Populophyllum reniforme* Font., *Sapindopsis magnifolia* Font., *Sapindopsis variabilis* Font., *Saliciphyllum parvifolium* Font., *Sphenolepidium Sternbergianum* (Dunk.) Heer, *Zamites tenuinervis* Font. etc	15-10
		Local unconformity with iron crusts.	
		Coarse, arkosic, cross-bedded, argillaceous sand exposed to water	5-10
		Total	28-42

RAPPAHANNOCK RIVER SECTIONS.

Exposures of the Patuxent are frequent in the vicinity of Fredericksburg, although they are for the most part covered with Eocene or surficial deposits. From Falmouth, about 1 mile above Fredericksburg, occasional exposures along the river show upwards of 30 feet of the arkosic gray sands of the Patuxent formation. A somewhat argillaceous lens of these materials near the steamboat landing at Fredericksburg yielded the large number of fossil plants for which this locality is famous. These have furnished the only adequate materials for a study of the Patuxent flora. The following are the more important forms identified from this locality:

Acrostichopteris adiantifolia (Font.) Berry
Acrostichopteris parvifolia Font.
Acrostichopteris pluripartita (Font.) Berry
Arthrotaxopsis grandis Font.
Carpolithus agglomeratus Font.
Carpolithus conjugatus Font.
Carpolithus curviatus Font.
Carpolithus fasciculatus Font.
Cephalotaxopsis brevifolia Font.
Cephalotaxopsis magnifolia Font.
Cladophlebis Albertsii (Dunk.) Brongn.
Cladophlebis distans Font.
Cladophlebis constricta Font.
Cladophlebis virginiensis Font.
Cladophlebis parva Font.
Cladophlebis Ungeri (Dunk.) Ward
Cladophlebis Browniana (Dunk.) Ward
Ctenis imbricata Font.
Ctenophyllum latifolium Font.
Ctenopteris insignis Font.
Ctenopteris longifolia Font.
Cycadeospermum ellipticum Font.
Dryopteris cystopteroides Font.
Dryopteris Dunkeri Font.
Equisetum Lyelli Mant.
Ficophyllum serratum Font.
Ficophyllum oblongifolium Font.
Frenelopsis ramosissima Font.
Leptostrobus longifolius Font.
Nageiopsis longifolia Font.
Nageiopsis angustifolia Font.
Nageiopsis zamioides Font.
Nilsonia densinerve (Font.) Berry
Onychiopsis goepperti (Schenck) Berry
Onychiopsis psilotoides (Stokes & Webb) Ward
Podozamites distantinervis Font.
Proteaephyllum ovatum Font.
Proteaephyllum reniforme Font.
Rogersia angustifolia Font.
Rogersia longifolia Font.
Ruffordia Goepperti (Dunk.) Seward
Sagenopteris virginiensis Font.
Scleropteris elliptica Font.
Sequoia ambigua Heer
Sequoia Reichenbachi (Gein) Heer
Sphenolepis Kurriana (Dunk.) Schenk
Sphenolepis Sternbergiana (Dunk.) Schenk
Taeniopteris auriculata (Font.) Berry
Taeniopteris nervosa (Font.) Berry
Thinnfeldia rotundiloba Font.
Thyrsopteris dentata Font.[1]
Thyrsopteris crenata Font.
Thyrsopteris divaricata Font.
Thyrsopteris crassinervis Font.
Thyrsopteris angustiloba Font.
Thyrsopteris heteroloba Font.
Thyrsopteris heteromorpha Font.
Thyrsopteris heterophylla Font.
Thyrsopteris nana Font.
Zamites crassinervis Font.
Zamites tenuinervis Font.
Zamiopsis insignis Font.
Zamiopsis laciniate Font.
Zamiopsis longipennis Font.
Zamiopsis petiolata Font.

Southeast of the town no Potomac materials are seen along the river for about 2 miles. Below this point, for a distance of about 6 miles or to about half a mile below the mouth of the Massaponax, the banks show occasional exposures of the usual gray coarse arkosic and more or less lithified sandstone of the Patuxent, which rises from 10 to 15 feet above tide and is overlain for the most part by Aquia Eocene. At the mouth of the Massaponax the following section occurs.

---

[1] These species of Thyrsopteris have not yet been restudied.

I. *Section left bank of Rappahannock River, opposite mouth of Massaponax Creek.*

		Feet
Pleistocene	Sand and gravel.......................about	12
Eocene. Aquia	Weathered argillaceous greensand...........	5
Lower Cretaceous. Patuxent	Coarse arkosic sand with gravel and angular clay pellets.............................	20
	Total...............................	37

The last exposure seen on the Rappahannock is along the right bank half a mile below Massaponax Creek, where the following section occurs:

II. *Section half mile below last, right bank.*

		Feet
Pleistocene	Mostly concealed...........................	20
Eocene. Aquia	Poorly exposed glauconitic sand.............	22
Lower Cretaceous. Patuxent	Coarse gravelly compact arkosic sand.........	12
	Total...............................	54

JAMES RIVER SECTIONS.

At Richmond the crystallines are exposed in the bed of the river, and their contact with the Patuxent is not seen, because of the low banks which are continuous for several miles below that town. Several low bluffs along the left bank between Richmond and Drewry's Bluff show a few feet of Patuxent arkosic argillaceous sands beneath 10 to 20 feet of Pleistocene. The section of Drewry's Bluff shows the best exposure of the Patuxent formation on the river and is continuous along the right bank for over half a mile. The lateral variation of the materials is considerable and affords an excellent idea of the marked changes in lithology which are typical of the Patuxent, particularly in this area.

I. *Section at Drewry's Bluff.*

			Feet
Pleistocene		Argillaceous, ferruginous sand	6
		Gravel bed	5
Lower Cretaceous.	Patuxent	Light gray coarse, arkosic sand	5-20
		Similar materials much cross-bedded and carrying gravel, cobbles, and clay balls	5-15
		Dark drab clay lenses in sand	5-10
		Indurated arkosic sand	12
		Coarse, arkosic, cross-bedded sand with clay balls and cobbles	15
		Total	53-83

As previously mentioned, the materials change so rapidly from point to point that no two sections of the bluff would be identical. The clay lens near the middle of the outcrop is very variable and the cobbles frequently tend to become aggregated into lenticular masses. Indurated layers a foot or two in thickness are also irregularly scattered through the bluff.

The next exposure is at Chaffin Bluff along the left bank one mile below the last.

II. *Section at Chaffin Bluff.*

			Feet
Pleistocene		Ferruginous, sandy clay	15
		Bed of cobbles	5
Lower **Cretaceous.**	**Patuxent**	Gray, arkosic sand	10
		Dark drab clay	15
		Total	45

This section also is extremely variable horizontally.

The next exposure about three miles below the last is along the right bank a short distance below Proctor Creek where the Patuxent is overlain by a remnant of Eocene materials.

III. *Section below Proctor Creek.*

			Feet
Pleistocene		Argillaceous, ferruginous sand about	10
		Course gravel with cobbles	8-10
Eocene		Glauconitic sands	5
Lower **Cretaceous.**	Patuxent	Indurated, coarse, arkosic, cross-bedded sands.	10-15
		Total	33-40

Below this exposure a short distance the crystallines show along the right bank and they are also exposed in the bed of a small stream which flows into the left bank about one and a half miles above Dutch Gap canal, these limited outcrops constituting the most easterly appearance of the Piedmont rocks in this area.

For about two miles before reaching Dutch Gap canal low exposures of the Patuxent formation overlain by a considerable thickness of Pleistocene are exposed along the left bank. The materials are grayish arkosic, cross-bedded sands with numerous clay lenses, some of which have yielded fossil plants, notably a low exposure about one mile above the canal where the following species have been collected:

Abietites longifolius (Font.) Berry
Abietites foliosus (Font.) Berry
Abietites macrocarpus Font.
Acrostichopteris pluripartita (Font.) Berry
Acrostichopteris cyclopteroides Font.
Acrostichopteris parvifolia Font.
Baiera foliosa Font.
Carpolithus virginiensis Font.
Carpolithus geminatus Font.
Carpolithus latus Font.
Carpolithus sessilis Font.
Ceptalotaxopsis brevifolia Font.
Cephalotaxopsis magnifolia Font.
Cladophlebis virginiensis Font.
Cladophlebis distans Font.
Cladophlebis Browniana (Dunk.) Seward.
Cladophlebis Ungeri (Dunk.) Ward.
Cladophlebis Albertsii (Dunk.) Brongn.
Cladophlebis oblongifolia Font.
Cladophlebis sphenopteroides Font.
Cycadeospernum ellipticum Font.
Dioonites Buchianus (Ett.) Born.
Equisetum Burchardti (Dunk.) Brongn.
Equisetum Lyelli Mant.
Ficophyllum crassinerve Font.
Gleichenia nordenskioldi Heer
Nageiopsis longifolia Font.
Nageiopsis zamioides Font.
Onychiopsis Goepperti (Schenk) Berry
Phyllocladopsis heterophylla Font.
Podozamites acutifolius Font.
Proteaephyllum tenuinerve Font.
Rogersia longifolia Font.
Ruffordia acrodentata (Font.) Berry
Ruffordia Goepperti (Dunk.) Seward.
Scleropteris elliptica Font.
Sphenolepis Kurriana (Dunk.) Schenk
Sequoia ambigua Heer
Sequoia delicatula Font.
Thinnfeldia granulata Font.
Thyrsopteris brevipennis Font.
Thyrsopteris divaricata Font.
Thyrsopteris meekiana Font.
Thyrsopteria angustifolia Font.
Thyrsopteris angustiloba Font.
Thyrsopteris nana Font.
Thyrsopteris ineaquipinnata Font.
Williamsonia virginiensis Font.
Zamites crassinervis Font.
Zamites tennuinervis Font.

Dutch Gap canal, celebrated historically, is 17 miles below Richmond. It is only about 100 yards in length and cuts off an oxbow of seven miles. Low exposures of Patuxent materials are equally well exposed in both banks and show in the following section, the following figures being a diagrammatic representation of the east bank.

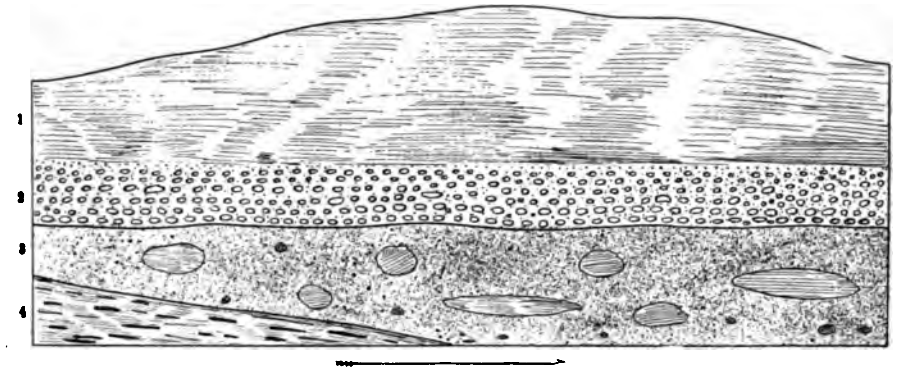

Fig. 1.—Dutch Gap Canal. Diagrammatic representation of the east bank.

IV. *Section on Dutch Gap Canal.*

			Feet
Pleistocene		1. Argillaceous sand grading down into gravel	20
		2. Cobble bed	5
Lower Cretaceous.	Patuxent	3. Coarse, arkosic gray sand with numerous pebbles, clay pellets, and clay balls. The latter are barren dark drab clay or hard brown clay or somewhat sandy brown clay with leaf impressions. Occasional lenses of sandy brown clay, indistinctly laminated carry good leaf impressions including *Acrostichopteris parvifolia* Font. *Acrostichopteris pluripartita* (Font.) Berry. *Arthrotaxopsis grandis* Font., *Cladophlebis oblongifolia Font.*, *Cladophlebis distans* Font., *Cladophlebis Browniana* (Dunk.) Seward, *Dioonites Buchianus* (Ett.) Born., *Dryopteris dentatum* Font., *Dryopteris macrocarpum* Font., *Leptostrubus foliosus* Font., *Nageiopsis longifolia* Font., *Nageiopsis zamioides.* Font., *Onychiopsis Goepperti* (Schenk) Berry, *Osmunda sphenopteroides* Font *Scleropteris elliptica* Font., *Sequoia Reichenbachi* (Gein) Heer. *Sphenolepis Kurriana* Schenk, *Thyrsopteris brevifolia* Font., *Thyrsopteris brevipennis* Font., *Thyrsopteris dentata* Font., *Thyrsopteris divaricata* Font., *Thyrsopteris obtusilobata* Font., and *Zamites tenuinervis* Font.	0-9
		4. Dark drab stratified, pyritiferous and lignitic clays	0-6
		Total	26-3

Above the lower entrance to the canal along the right bank of the old river channel the Potomac Group is exposed more or less continuously for a distance of between 3 and 4 miles as far as the Howlett House bluff. At this point the following section is seen:

V. *Section at Howlett House Bluff.*

		Feet
Pleistocene. Sunderland	Yellowish sandy loam..................about	45
Miocene. Calvert	Fine yellow sand clay..................about	35
Eocene. Aquia	Glauconitic argillaceous sand becoming indurated below..............................	15
Lower Cretaceous. Patuxent	Coarse gravelly sand	10
	Cross-bedded, arkosic sand..................	18
	Similar materials with cobbles. Indurated in places	2
	Total................................	125

Between this point and the lower entrance to the canal clay lenses of very limited extent, and clay balls, have furnished the following fossil plants:

Acrostichopteris parvifolia Font.
Acrostichopteris pluripartita (Font.) Berry
Araucaria obtusifolia Font.
Araucarites virginious Font.
Brachyphyllum crassicaule Font.
Cladophlebis Albertsii (Dunk.) Brongn.
Cladophlebis Browniana (Dunk.) Seward.
Cladophlebis Ungeri (Dunk.) Ward
Dioonites Buchianus (Ett.) Born.
Frenelopsis parceramosa Font.
Onychiopsis Goepperti (Schenck) Berry
Ruffordia Goepperti (Dunk.) Seward.
Sphenolepis Kurriana (Dunk.) Schenk
Thyrsopteris angustifolia Font.
Thyrsopteris angustiloba Font.
Thyrsopteris rarinervis Font.
Williamsonia virginiensis Font.

The next and last exposure of Potomac Group on the James River is at Deep Bottom, 4 miles below Dutch Gap on the left bank just below Three Mile Creek. At this point the following section is seen in the ravine of the creek.

VI. *Section at Deep Bottom.*

		Feet
Pleistocene	Argillaceous sand and loam..................	10-20
	Gravel bed	5-10
Eocene	Glauconitic argillaceous sand...............	4-5
Lower Cretaceous. Patapsco	Exposed about............................	3
	Arkosic sand with cobbles above and containing lenses and balls of sandy brownish clay carrying leaf impressions including *Araliaephyllum crassinerve* (Font.) Berry, *Cladophlebis constricta* Font., *Ficophyllum crassinerve* Font., *Juglandiphyllum integrifolium* Font., *Nageiopsis longifolia* Font., *Podozamites acutifolius* Font., *Populophyllum crassinerve* Font., *Sapindopsis magnifolia* Font., *Sassafras bilobata* Font., *Sphenopteris latiloba* Font., *Sterculia elegans* Font., *Thyrsopteris brevipennis* Font., and *Ulmiphyllum crassinerve* Font.............................	
	Total................................	22-38

While the lithology of the Potomac portion of this exposure is not to be differentiated from that of the preceding sections the fossils indicate that it represents a remnant of the Patapsco formation, the most southerly one known, as well as the only recognizable exposure of this age on the James River, marking the point where the Potomac dissappears beneath tide.

APPOMATTOX RIVER SECTIONS.[a]

No satisfactory exposures of Potomac strata occur at Petersburg although low exposures of Patuxent arkosic sand are to be seen in various road cuttings in the vicinity of the town. The river banks are low for some miles below, the only notable Potomac section on the river being that at Point of Rocks, although the Patuxent is exposed more or less along the right bank for some 3½ miles above the Point. The banks are much slipped and poorly exposed and furnish nothing worthy of comment except occasional traces of plant fossils, none of which are complete enough for accurate identification.

At Point of Rocks, which is on the left bank about 4 miles above City Point, the only good section on the river shows the following details:

I. *Section at Point of Rocks.*

		Feet
Pleistocene	Argillaceous sand with gravel bed containing cobbles along the base	5-12
Lower Cretaceous. Patuxent	Lenticularly cross-bedded coarse arkosic sand with scattered cobbles in places, firmly and extensively indurated	75-80
	Total	92

The minor details of this section are very variable, no two points along the bluff showing exactly the same succession.

Below Point of Rocks the left bank of the Appomattox is low and shows no exposures while along the right bank for a distance of about two miles occasional poor exposures of Potomac materials rise from 10 to 20 feet above tide and are overlain with Eocene or Pleistocene. One of these about one and a fourth miles below Point of Rocks shows the following section:

---

[a] The writer had the benefit of Mr. Arthur Bibbins notes of the Appomattox River section.

II. *Section below Point of Rocks.*

			Feet
Pleistocene		Argillaceous loam with gravel at base	10
Eocene.	Aquia	Weathered glauconitic argillaceous sand exposed	12
		Concealed	6
Lower Cretaceous.	Patuxent	Arkosic sand with scattered pebbles	16
		Total	34

The last exposures of the Potomac Group on the Appomattox River are about three miles above City Point at a locality known as Figs Wharf where from 10 to 15 feet of coarse arkosic sand apparently of Patuxent age is overlain with from 10 to 20 feet of Aquia greensand.

SECTIONS ALONG THE RICHMOND, FREDERICKSBURG AND POTOMAC RAILROAD.

A large number of sections showing Potomac outcrops are to be seen along the line of the R. F. & P. R. R. between Alexandria and Fredericksburg of which the following are the more representative:

I. *Section in cut one-half mile north of Accotink.*

			Feet
Pleistocene		Ferruginous sand and gravel	10
Lower Cretaceous.	Patuxent	Cross-bedded arkosic gray sands more or less lithified with occasional balls of greenish hackly clay	40
		Total	50

II. *Section in cut just north of Accotink.*

			Feet
Pleistocene		Ferruginous gravel with boulders	2-5
Lower Cretaceous.	Patuxent	Brownish sandy clay with plant fragments	0-6
		Cross-bedded coarse gray arkosic sand	5
		Very sandy brownish clay	2-3
		Total	9-19

III. *Section in second cut south of Accotink.*

			Feet
Pleistocene		Sand and gravel with cobbles and boulders up to 3 feet in diameter	2-10
Lower Cretaceous.	Patuxent	Coarse arkosic cross-bedded sands with clay pellets	10-15
		Iron crusts	6 ins.
		Greenish black clay	4-6
		Total	17-31

The Patuxent surface is very uneven and angular. Supposed Lafayette cobbles and boulders fill the erosion pockets.

IV. *Section in cut just north of Pohick.*

			Feet
Pleistocene		Ferruginous gravel	5-6
Lower Cretaceous.	Patuxent	Coarse cross-bedded gray arkosic pebbly sand	10-15
		Total	15-21

V. *Section in cut south of Pohick.*

			Feet
Pleistocene		Brownish sand with gravel and cobbles	10-15
Lower Cretaceous.	Patuxent	Lithified gray cross-bedded arkosic sand with thin lenses of drab clay	10
		Total	20-25

VI. *Section in cut one-quarter mile south of Lorton.*

			Feet
Pleistocene		Coarse buff sand and gravel with occasional cobbles	4-5
Lower Cretaceous.	Patuxent	Coarse gray arkosic cross-bedded sand	10
		Laminae, pellets and balls of drab clay with leaf impressions, including *Brachyphyllum parceramosum* Font., *Dioonites Buchianus* (Ett.) Born., *Nageiopsis angustifolia Font.*, *Nageiopsis longifolia* Font., *Podozamites acutifolius* Font., *Podozamites distantinervis* Font., *Sequoia ambigua* Heer, *Sphenolepidium Kurrianum* (Dunk.) *Heer*, *Sphenolepidium Sternbergianum* (Dunk.) Heer, *Scleropteris elliptica* Font., *Zamites tenuinervis* Font., etc.	2
		Greenish sandy clay	0-5
		Total	16-22

The next important cut is that just south of Freestone which is given in the Potomac River sections.

VII. *Section in cut south of Powells Creek.*

			Feet
Pleistocene		Ferruginous sand and gravel	2-5
Eocene.	**Aquia**	Argillaceous glauconitic sands	10-20
Lower Cretaceous.	**Patapsco**	Sandy, arkosic, cross-bedded sand with scattered pebbles, clay pellets, and some large clay balls	30-50
		Total	42-75

The next section near Cherry Hill shows similar Patuxent materials rising for some 30 feet above the track directly overlain by 10 feet of surficial deposits, the Aquia being cut out.

From this point to Aquia Creek no good outcrops of Potomac materials are exposed although low exposures of the usual arkosic sands are seen at intervals overlain by Eocene or Pleistocene materials.

VIII. *Section in first cut south of Aquia Creek.*

		Feet
Pleistocene	Sandy loam and soil........................	6
Eocene. Aquia	Glauconitic sand, sparingly fossiliferous......	15
Lower Cretaceous. Patapsco	Coarse cross-bedded gray sand with iron crusts	15
	Greenish and drab arenaceous leaf-bearing clays with *Acrostichopteris longipennis* Font., *Nelumbites tenuinervis* (Font.) Berry, *Populophyllum reniforme* Font., *Sapindopsis brevifolia* Font., *magnifolia* Font., and *variabilis* Font., *Sphenolepidium sternbergianum* (Dunk.) Heer, etc......................	20
	Coarse cross-bedded arkosic sand with pebbles and clay pellets..........................	18
	Lighter more argillaceous arkosic materials exposed to R. R. track....................	15
	Total..............................	89

The track is about 20 feet above tide, and up the creek a short distance variegated Patapsco clays are visible near the water's edge.

IX. *Section at 72-mile Post.*

		Feet
Pleistocene	Pebbly soil grading down into coarse reddish argillaceous sand with pebbles and clay pellets	5
	Unconformity	
Eocene. Aquia	Glauconitic argillaceous sands.............	20-25
Lower Cretaceous. Patapsco	Argillaceous sand with local cobbles up to 5 inches in diameter.......................	1
	Brown sandy clay with leaf impressions.......	1-2
	Drab argillaceous sand	1-2
	Coarse, arkosic, gray, argillaceous ferruginous cross-bedded sand, carrying pebbles........	6-8
	Total...............................	43

The plant remains from this locality include the following, about half of which are Dicotyledonæ:

Araliaephyllum magnifolium Font.
Araliaephyllum crassinerve (Font.)
Aristolochaephyllum crassinerve Font.
Arthrotaxopsis grandis Font.
Brachyphyllum crassicaule Font.
Celastrophyllum acutidens Font.
Celastrophyllum parvifolium (Font.) Berry
Cladophlebis Browniana (Dunk.) Seward.
Cladophlebis crenata Font.
Cladophlebis constricta Font.
Dryopteris virginica Font.
Hederaephyllum dentatum (Font.) Berry
Myrica brookensis Font.
Myricaephyllum dentatum Font.
Nageiopsis angustifolia Font.
Nageiopsis longifolia Font.
Nelumbites virginiensis (Font.) Berry
Onychiopsis Goepperti (Schenk) Berry
Onychiopsis psilotoides (Stokes and Webb) Ward
Populophyllum grossedentatum Font.
Sapindopsis brevifolia Font.
Sapindopsis magnifolia Font.
Sapindopsis variabilis Font.
Sassafras bilobata Font.
Sassafras parvifolium Font.
Dichotozamites cycadopsis Font.
Sphenolepis Kurriana (Dunk.) Schenk
Sphenolepis Sternbergiana (Dunk.) Schenk
Thinnfeldia Fontainei Berry
Torreya virginica Font.
Ulmophyllum brookense Font.
Widdringtonites ramosus (Font.) Berry

X. *Section near Brooke.*

			Feet
Eocene. Aquia		Argillaceous glauconitic sand........... about	40
Lower Cretaceous.	Patapsco	Light gray massive arkosic coarse sand with pebbles, clay balls and clay lenses with leaf impressions indurated in the lower part .... about	20
		Total......................... about	60

The plant remains from near Brooke include:

Acrostichopteris longipennis Font.
Acrostichopteris pluripartita (Font.) Berry
Araucarites aquiensis Font.
Carpolithus brookensis Font.
Cladophlebis Browniana (Dunk.) Seward
Dryopteris ellipticum Font.
Dryopteris pinnatifidum Font.
Nageiopsis angustifolia Font.
Nelumbites virginiensis (Font.) Berry
Podozamites acutifolius Font.
Sapindopsis brevifolia Font.
Sapindopsis magnifolia Font.
Sapindopsis variabilis Font.
Sphenolepis Kurriana (Dunk.) Schenk

The following table shows the geographical distribution in the Virginia area of the various members of the Potomac flora.

TABLE SHOWING THE DISTRIBUTION OF THE POTOMAC FLORA.

	PATUXENT FORMATION.												PATAPSCO FORMATION									
	Colchester Road.	Lorton (Telegraph) Station.	Cockpit Point.	Potomac Run.	Kankeys.	Woodbridge.	Fredericksburg.	Alum Rock.	Dutch Gap.	Trents Reach.	Neabsco Creek.	Chinkapin Hollow (Lower).	Chinkapin Hollow (Upper).	Mt. Vernon.	White House Bluff.	Hell Hole.	Dumfries Landing.	Widewater.	Aquia Creek.	Brooke.	72 mile post.	Deep Bottom.
FILICALES.																						
Schizaeopsis americana							●		●	●												
Ruffordia acrodentata									●													
Ruffordia Goepperti							●		●	●												
Acrostichoptertis cyclopteroides									●													
Acrostichopteris adiantifolia		●		●			●					●										
Acrostichopteris parvifolia				●			●		●	●												
Acrostichopteris pluripartita		●					●		●	●						●				●	●	
Acrostichopteris longipennis														●	●	●	●	●	●	●	●	
Cladophlebis Browniana		●		●			●	●	●			●								●		
Cladophlebis constricta							●									?				●		●
Cladophlebis rotundata							●		●			●		●								
Cladophlebis virginiensis				●			●		●			●										
Cladophlebis parva			●	●			●															
Cladophlebis Albertsii		●		●			●		●	●												
Cladophlebis Ungeri		●				●	●		●			●										
Cladophlebis distans		●					●		●			●										
Dryopteris macrocarpa									●													
Dryopteris pinnatifida																				●		
Dryopteris cystopteroides							●															
Dryopteris elliptica				●																●		
Dryopteris dentata		●		●					●													
Dryopteris virginica							●													?		
Aspleniopteris pinnatifida							●															
Aspleniopteris adiantifolia							●															
Onychiopsis latiloba		●					●		●					●		?	?					
Onychiopsis psilotoides				●			●		●	●						●		●		●		
Onychiopsis brevifolia		●		●			●		●													
Onychiopsis Goepperti	●		●	●			●		●	●		●		●	●		●			●		
Onychiopsis nervosa				●			●		●			●										
Sagenopteris latifolia		●																				
Sagenopteris elliptica				●	●																	
Sagenopteris virginiensis							●															
Taeniopteris auriculata				●			●															
Taeniopteris nervosa		●		●			●															
Scleropteris elliptica		●	?	●	●		●		●			●										
Thinnfeldia fontainei				●											●					●		
Thinnfeldia granulata		●		●						●												
Thinnfeldia rotundiloba				●			●															
Gleichenia nordenskioldi									●													
Osmunda dicksonioides				●																		
Osmunda sphenopteroides									●													
Polypodium dentatum							●															
Polypodium fadyenioides				●																		
Sphenopteris grevilloides														●	●							
EQUISETALES.																						
Equisetum Lyellii							●		●													
Equisetum Burchardti		●	●						●													
CYCADOPHYTA.																						
Dioonites Buchianus		●	●		●				●	●												
Ctenopteris insignis				●			●															
Ctenopteris angustifolia				●								●										
Ctenopteris longifolia							●															
Ctenopsis latifolia							●															
Zamiopsis dentata							●															

TABLE SHOWING THE DISTRIBUTION OF THE POTOMAC FLORA.

	PATUXENT FORMATION.												PATAPSCO FORMATION.									
	Colchester Road.	Lorton (Telegraph) Station.	Cockpit Point.	Potomac Run.	Kankeys.	Woodbridge.	Fredericksburg.	Alum Rock.	Dutch Gap.	Trents Beach.	Neabsco Creek.	Chinkapin Hollow (Lower).	Chinkapin Hollow (Upper).	Mt. Vernon.	White House Bluff.	Hell Hole.	Dumfries Landing.	Widewater.	Aquia Creek.	Brooke.	72 mile post.	Deep Bottom.
Zamiopsis petiolata							●															
Zamiopsis laciniata							●															
Nilsonia Rogersi												●										
Nilsonia densinerve							●															
Zamites tenuivervis					●		●		●					●			●	●				
Zamites crassivervis				●	●		●		●													
Dichotozamites cycadopsis														●						●		
Cycadeospermum acutum				●				●														
Cycadeospermum rotundatum					●																	
Cycadeospermum spatulatum				●			●		●													
Podozamites grandifolius				●			●															
Podozamites subfalcatus		●																		●	●	
Podozamites acutifolius		●							●											●		●
Podozamites inaequilateralis			●	●	●																	
Podozamites distantinervis				●			●		?													
Podozamites knowltoni														●								
Podozamites lanceolatus		●																				
Williamsonia virginiensis									●	●												
Ctenis imbricta							●															
GYMNOSPERMAE.																						
Baiera foliosa									●													
Nageiopsis longifolia		●	●	●	●		●		●				?	●						●		?
Nageiopsis angustifolia				●			●		●					●						●		
Nageiopsis zamiodes			●	●			●		●			●										
Cephalotaxopsis magnifolia				●			●		●													
Cephalotaxopsis brevifolia				●			●		●													
Brachyphyllum crassicaule									●	●							●	●		●		
Brachphyllum parceramosum		●																				
Araucarites aquiensis													●	●				●	●	●		
Araucarites patapscoensis																		●				
Abietites macrocarpus							●		●													
Abietites longifolius				●			●		●					●		●				●	●	
Abietites foliosus									●													
Pinus vernonensis														●				●				
Cupressinoxylon columbianum									●													
Cupressinoxylon Wardi											●											
Frenelopsis ramosissima							●					●				?						
Frenelopsis parceramosa										●												
Sphenolepis Kurriana		●	●	●	●		●		●	●				●		●						
Sphenolepis Sternbergiana		●	●	●		●	●	●					●	●	●	●	●	●	●	●	●	
Laricopsis augustifolia									●	●												
Arthrotaxopsis expansa		●	●	●			●		●													
Arthrotaxopsis grandis							●		●													
Widdringtonites ramosus														●	●	●				●	●	
Sequoia Reichenbachi		●					●		●											●		
Sequoia rigida		●		●																		
Sequoia delicatula									●													
Sequoia ambigua		●	●	●			●		●													
Tumion falcatum				●																		
Tumion virginicum																				●		
Phyllocladopsis heterophila									●													
Leptostrobus ? multiflorus																				●		
Feistmantelia virginica			●																			
Feildeniopsis crassinervis					●																	
Ephedrites ? vernonensis														●								
Araucaria obtusifolia										●												
Araucaria podocarpoides																				●		
Araucaria zamioides				●																		

TABLE SHOWING THE DISTRIBUTION OF THE POTOMAC FLORA.

	Patuxent Formation.												Patapsco Formation.									
	Colchester Road.	Lorton (Telegraph) Station.	Cockpit Point.	Potomac Run.	Kankeys.	Woodbridge.	Fredericksburg.	Alum Rock.	Dutch Gap.	Trents Reach.	Neabsco Creek.	Chinkapin Hollow (Lower).	Chinkapin Hollow (Upper).	Mt. Vernon.	White House Bluff.	Hell Hole.	Dumfries Landing.	Widewater.	Aquia Creek.	Brooke.	72 mile post.	Deep Bottom.
Angiospermae.																						
Alismaphyllum Victor Masoni														●								
Populus potomacensis														●	●							
Populophyllum minutum														●								
Populophyllum reniforme														●	●			●	●		●	
Nelumbites virginiensis														●		●				●	●	
Nelumbites tenuinervis														●	●				●			
Sapindopsis variabilis														●	●			●	●	●	●	
Sapindopsis magnifolia															●			●	●	●	●	?
Sapindopsis brevifolia																			●	●	●	
Celastrophyllum parvifolium																●					●	
Celastrophyllum acutidens													●		●			●			●	
Sassafras bilobatum																?				●		
Sassafras parvifolium																				●		
Sassafras potomacensis																	●	●				
Araliaephyllum crassinerve																				●		●
Araliaephyllum magnifolium																				●	●	
Hederaephyllum dentatum																				●		
Ficophyllum serratum							●															
Ficophyllum oblongifolium				●			●		●													
Proteaephyllum reniforme							●		●													
Proteaephyllum ovatum				●			●		●													
Rogersia longifolia					●		●		●													
Rogersia angustifolia				●			●															
Aristolochiaephyllum crassinerve																●				●	●	
Aristolochiaephyllum ? cellulare														●								
Menispermites potomacensis																		●				
Antholithus gandium-rosae														●								
Aralia ? vernonensis														●								
Casuarina covillei														●								
Hymenaea virginiensis																				●		
Potamogetophyllum vernonense														●								
Quercophyllum grossedentatum																				●		
Sterculia elegans														●								●
Ulmophyllum brookense																				●		●

UPPER CRETACEOUS.

In New Jersey deposits of Upper Cretaceous age are extensively developed and appear at the surface over a wide belt which crosses the entire State from northeast to southwest. Below the Delaware River in Delaware and Maryland the width of this belt gradually decreases through the overlapping of the Eocene beds and in the region of the Potomac River the deposits disappear entirely and have not as yet been found at the surface anywhere in Virginia. That Upper Cretaceous deposits form a part of the Coastal Plain of this State, however, is certain as at least five deep-well borings in the vicinity of Norfolk and one at Fairport in Northumberland County have revealed their presence between the Eocene and Potomac deposits. Darton[a] estimates the total thickness of these beds to be at least 65 feet and possibly considerably more. The materials consist of greensand, micaceous sand, dark sandy lignitic clay, stiff clay, fine sand, coarse gray sand, pebbles, and shells.

The Upper Cretaceous age of the deposits is determined by the fossils which have been brought to the surface. In the Norfolk Water Works well an *Exogyra* somewhat resembling *Exogyra ponderosa* was very abundant in the materials penetrated between the depths of 700 and 775 feet. In the well at Lambert Point, Norfolk, a bed between 563 and 610 feet yielded the following forms: *Exogyra ponderosa, Astarte octolirata, Ostrea plumosa, Gouldia* (?) *decemnaria, Gryphea vesicularis, Liopistha* (*Cymella*) *bella, Corbula* sp., *Modiolus* sp., and *Baculites* (?). In the well at the Chamberlain Hotel, Old Point Comfort, fragments of *Terebratula harlani* (?) were obtained.

In New Jersey the Upper Cretaceous is divided from below upward into the Raritan, Magothy, Matawan, Monmouth, Rancocas, and Manasquan formations, each characterized by distinct lithological and faunal features. The data obtained from the few deep-well sections about Norfolk and Fairport are too meagre to determine definitely just what formations are present but it seems probable that more than one horizon is represented in this part of Virginia. The dark sandy micaceous clays penetrated in the Norfolk Water Works well and in the Chamberlain Hotel well resemble the materials which compose so large a proportion of the Matawan formation in Maryland and New Jersey and the fossils from the Lambert Point well are characteristic of that horizon.

In New Jersey the fossil *Terebratula harlani* has been found only in the Rancocas formation while the other fossils are characteristic of lower beds.

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[a] Darton, N. H., U. S. Geol. Survey Folio, No. 80.

CENOZOIC

TERTIARY.

The Tertiary deposits of Virginia form part of a complex series of formations that extend interruptedly from New Jersey southward to the Gulf of Mexico. At no point in the region is the series more complete or better exposed than in the Chesapeake Bay drainage basin, the bluffs along the Maryland and Virginia streams having long been classic ground for the study of American Tertiary strata. These Tertiary beds overlie unconformably the Cretaceous deposits which they gradually transgress landward. The Tertiary of Virginia is represented by deposits of Eocene, Miocene, and Pliocene (?).

EOCENE.

THE PAMUNKEY GROUP.

The Eocene strata of the Middle Atlantic Coastal Plain form a belt of varying width, extending from northeast to southwest, somewhat to the west of the center of the Coastal Plain. This belt has been traced almost continuously from the Maryland-Delaware line to the valley of the Nottoway River in southern Virginia. Although in places buried beneath later deposits, fine exposures of Eocene strata occur along all the leading stream-channels, while not infrequently broad outcrops of the beds appear at the surface in the intervening country.

The Eocene deposits overlie the Cretaceous formations unconformably and consist largely of greensand marls which may, however, by weathering, lose their characteristic green color, and by the deposition of a greater or less amount of hydrous iron oxide become firm, red or brown sandstones or incoherent red sands. In certain places, notably in southern Maryland and Virginia, the strata become highly argillaceous, the glauconitic elements largely or entirely disappearing. Infrequently coarse sands and even gravels are found, the latter chiefly toward the base of the deposits and near the ancient shore-line. Very commonly the shells of organisms are so numerous as to form the chief constituent of certain beds, which occasionally become cemented by calcium carbonate to form impure limestones.

Notwithstanding the fact that several different kinds of materials are found composing the Eocene beds, the deposits on the whole are remarkably homogeneous. There is seldom any difficulty experienced in drawing the line of separation between the Eocene strata and the overlying and underlying formations. The great amount of glauconite in the Eocene deposits and the homogeneity of the deposits as a whole, at once separate them from the extremely variable and highly colored sands and clays of the Potomac formations below, and from the blue clays, light colored sands, and diatomaceous earth beds of the overlying Miocene.

Even though the Eocene deposits have characters so persistent that they can readily be separated from adjacent formations, yet recent investigations have shown the possibility of dividing the deposits into two well-marked formations on both lithologic and faunal grounds. These formations have received the names of Aquia and Nanjemoy. The Eocene deposits of Maryland and Virginia were first supposed to constitute a single stratigraphic unit which was called the Pamunkey formation. Since the division of the deposits into two formations the term Pamunkey is retained as a group name. The lower or Aquia formation is much more highly arenaceous than the upper or Nanjemoy formation which, particularly in its lower part, is generally highly argillaceous. The Aquia formation is also much more calcareous than the Nanjemoy formation, indurated layers frequently appearing in the former. Both formations are, however, highly glauconitic.

The most complete section of the Eocene strata in the Middle Atlantic Slope is afforded by the series of high bluffs on the western bank of the Potomac River between Aquia Creek and Mathias Point, in eastern Stafford and King George counties. The peninsula between the Potomac and Rappahannock rivers is to a large extent formed of the Eocene greensands, which also appear along the banks of the latter stream, outcropping beneath the Columbia formations. The higher levels of the intervening country are, however, generally capped by the Miocene and Columbia formations.

The Eocene deposits are continued southward in Spottsylvania and Caroline counties. Fine bluffs of the characteristic marls appear on the south bank of the Rappahannock at several points above Port Royal, but in the valley of the Mattaponi they are much less prominent although occurring at frequent intervals. An extensive cover of later deposits occupies the higher portions of the country. In the valley of the Pamunkey River and its tributaries, particularly in Hanover County, important outcrops of Eocene strata are found. For this reason the name Pamunkey was first selected as the name for the formation. Many of the fossils described by Conrad and Rogers were obtained along the Pamunkey River.

Farther south, in the valley of the James River, there are many excellent outcrops of Eocene material exposed at intervals from Richmond to a short distance below City Point, while there are some exposures along the lower course of the Appomattox River. South of the Appomattox the only exposures thus far known are in the vicinity of Bollings Bridge, on the Nottoway River.

The Aquia Formation.

Name.—The formation receives its name from Aquia Creek, a stream which empties into the Potomac River in Stafford County. Along the lower course of this stream as well as along the banks of the Potomac River near its mouth are found several fine exposures. The name was proposed by W. B. Clark[a] in 1895, and further defined in 1896[b].

Stratigraphic relations.—The Aquia formation rests unconformably upon the irregularly eroded surface of the Potomac formations. In the northern portion of the State it overlies the Patapsco, while in the James River basin it rests upon the exceedingly uneven surface of the Patuxent formation. In the latter locality the most marked unconformities thus far recognized in the Virginia Coastal Plain are found. Thus along Shockoe and Gillis creeks in Richmond and along the tributaries of the Appomattox River a few miles north of Petersburg the Aquia is exposed only a little above tide, while along the strike of these exposures and even to the east of them at Drewry's Bluff, Howlett House Bluff, the high bluff above the Dutch Gap canal, on the James River, and at Point of Rocks on the Appomattox River the Patuxent is found rising from 40 to 80 feet above tide. At Point of Rocks the Patuxent would be expected to occur at from 25 to 30 feet below tide, as the Aquia deposits at Ashton Creek, two miles directly west, are almost at tide, but instead of this the Patuxent rises about 80 feet above tide. No faulting has apparently occurred. Thus in the distance of about two miles there is an apparent unconformity amounting to about 100 feet. The Aquia is conformably overlain by the Nanjemoy formation or unconformably by the unconsolidated deposits of the Pleistocene where the Nanjemoy is wanting.

Lithologic character.—The Aquia formation consists primarily of greensands and greensand marls interbedded with which are occasionally layers composed almost entirely of shells. The latter often become thoroughly indurated. Such beds are excellently exposed near the mouth of Aquia Creek and near the tops of the divides east of Stafford. The greensand on weathering frequently becomes reddish-gray, yellow, or reddish-brown in color. Argillaceous beds occur but there is much less clay in the Aquia than in the Nanjemoy formation. The greater portion of the strata constituting the Aquia formation seems to have been accumulated in quiet and probably relatively deep water, as the bedding planes are very regular and the materials are largely fine sand. While the basal beds of the Aquia were being formed the water was probably shallower and the shore-line closer, as we find in these beds some small pebble bands which are absent in the higher beds. The general character of the formation is shown in the detailed sections given on a subsequent page.

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[a] Johns Hopkins Univ. circ., vol. xv, 1896, pp. 3.

[b] Bull. U. S. Geol. Survey, No. 141, p. 39.

Strike, dip, and thickness.—The strike of the Aquia formation is almost due north and south and the beds dip to the east at the rate of from 12 to 15 feet to the mile. This dip has been determined from surface exposures in the region of outcrop in Stafford County and probably continues at about the same rate after it passes at tide beneath the overlying formations as the base of the Eocene is found at a depth of 840 feet in the new government well at Fortress Monroe.

The thickness of the Aquia formation in Stafford County is about 100 feet, and this thickness is probably rather constant throughout the Coastal Plain. In the Fortress Monroe well just mentioned the total thickness of the Eocene is only a little in excess of 200 feet and if half of that thickness represents the Aquia, as seems probable, the formation will be seen to maintain about the same thickness even down the dip.

Divisions.—The Aquia formation has been divided into two members known as the *Piscataway* indurated marl and *Paspotansa* greensand marl, each having a thickness of about 50 feet. The Piscataway member is characterized by greensands and greensand marls, the lower beds often very argillaceous. The well-marked and rather persistent layers of indurated marl characterizes the upper beds in the Potomac region. The Paspotansa member is composed of a thick bed of greensand, overlain by thick-bedded, indurated layers of greensand marl. The Piscataway member in the Potomac region is again divided into seven zones and the Paspotansa member into two zones. The two members show paleontological differences to which reference will be made later.

Paleontological character.—The Aquia formation has yielded a great many fossils belonging to most of the groups of the invertebrates as well as to the fishes and reptiles among the vertebrates. The molluska, especially the Pelecypoda and Gastropoda, are represented by countless individuals and by many species. All are marine forms. Many of the Aquia species are limited to this formation although a considerable number survived during the deposition of the Nanjemoy.

Among the forms which are restricted to the Aquia formation but found in both its members are:

Turritella mortoni Conrad
Turritella humerosa Conrad
Scala virginiana Clark
Gibbula glandula (Conrad)
Panopea elongata Conrad
Meretrix ovata var. *pyga* (Conrad)
Dosiniopsis lenticularis (Rogers)
Lucina aquiana Clark
Venericardia planicosta var. *regia* Conrad
Crassatellites alaeformis Conrad
Crassatellites aquiana Clark
Ostrea compressirostra Say
Leda cliftonensis Clark and Martin
Trochocyathus clarkeanus Vaughan
Eupsammia elaborata (Conrad)

The following species among others have been found only in the Piscataway member:

Trionyx virginiana Clark
Synechodus clarkii Eastman
Odontaspis elegans (Agassiz)
Phenacomya petrosa (Conrad)
Pholadomya marylandica Conrad
Lithophaga marylandica Clark and Martin
Ostrea compressirostra var. *alepidota* Dall

The following species among others have been found only in the Paspotansa member:

Pleurotoma harrisi Clark
Pleurotoma potomacensis Clark and Martin
Cancellaria potomacensis Clark and Martin
Mitra pomonkensis Clark and Martin
Tudicla marylandica Clark and Martin
Calyptraphorus jacksoni Clark
Aporrhais potomacensis Clark and Martin
Diplodonta marlboroensis Clark and Martin
Crassatellites alta (Conrad)
Platidia marylandica Clark and Martin
Paracyathus marylandicus Vaughan
Balanophyllia desmophyllum Milne Edwards and Haime.

Areal distribution.—The Aquia formation outcrops along all the important streams and many of their tributaries in a narrow belt extending from the Potomac River to the James River and passing through the counties of Stafford, King George, Caroline, Hanover, Henrico, Chesterfield, and Prince George with one isolated locality along the Nottoway River in Sussex County. The base of the formation rises above tide on Aquia Creek about one-half mile east of the railroad crossing, about the same distance east of the railroad on Potomac Creek, about 7 miles below Fredericksburg on the Rappahannock, near the mouth of Massaponax Creek and at Deep Bottom on the James River. From these places the formation gradually rises toward the west, appearing at higher and higher levels along the valley slopes until it reaches to the height of the stream divides, where it is either exposed or covered with a thin capping of Lafayette or Columbia materials. The line of separation between the Aquia and Nanjemoy has only been determined in a few places because of the lack of suitable exposures. Along the Potomac River the Aquia appears above tide from beneath the Nanjemoy deposits about 4 miles below the mouth of Potomac Creek. The line of contact can be followed to the west to the top of the divides between the Potomac and Rappahannock rivers a short distance to the east of the R. F. and P. R. R. The Aquia formation is also excellently exposed in numerous places along nearly all the minor streams to the east of the railroad in Stafford County and in many places along the lower courses of the leading streams in northeastern Spottsylvania, northwestern Caroline, and western King George counties. Along the James River the Aquia formation appears in Richmond along Shockoe Creek beneath the clay and diatomaceous earth deposits of the Calvert formation, and is similarly exposed in the valleys of Gillis and Almond creeks. Probably the Eocene deposits exposed along the Nottoway River in Sussex County also belong to the Aquia formation.

DETAILED SECTIONS.

SECTIONS IN POTOMAC RIVER VALLEY.

The Aquia formation is best exposed in the valley of the Potomac River and its tributaries. Exposures can be traced from the high lands bordering the District of Columbia southeastward until the formation reaches tide along the Maryland bank of the Potomac River in Charles County and on Aquia Creek in Stafford County, Virginia. Several sections from the Maryland bank of the Potomac are given in order to show the relations and detailed stratigraphy of the formation.

I. *Section at Glymont, north of wharf and ravine.*

				Feet
Pleistocene			Gravel and loam	20
Eocene.	**Aquia**	Piscataway	Light green glauconitic sand, underlain by argillaceous sand, with few fossils (Zone 4)	10
			Indurated greensand (Zone 3)	1
			Greenish marl with numerous fossils including *Ostrea compressirostra*, *Crassatellites alaeformis*, *Turritella mortoni*, *Dosiniopsis lenticularis*, *Meretrix ovata* var. *pyga*, *etc.* (Zone 2)	21
			Argillaceous glauconitic sand for the most part without fossils, but containing indeterminate plant remains and molluscan casts at the base (Zone 1)	8
Lower Cretaceous.	Patapsco		Variegated clays of the Potomac group	20
			Total	80

II. *Section two miles up Aquia Creek.*

				Feet
Pleistocene			Gravel and sand	7
Eocene.	Aquia	Piscataway	Indurated greensand (Zone 3)	1
			Greensand with characteristic fossils (Zone 2)	15
			Argillaceous sand more or less glauconitic without fossils (Zone 1)	18
			Total	41

III. *Section of western portion of bluff at Aquia Creek.*

				Feet
Pleistocene			Fine sand, light-yellow in color, with white clay near the base	26
Eocene.	Aquia	Paspotansa	Fine sand, of light-greenish color, containing a few glauconitic grains (Zone 10)	10
			Thick-bedded, arenaceous, and glauconitic limestone interstratified with unconsolidated layers of partially weathered greensand, the indurated layers largely filled with the shells of *Turritella mortoni* (Zone 9)	10
			Fine sand, of gray or green color, containing several irregular bands of *Turritella mortoni*, also *T. humerosa*, *Cucullaea gigantea*, *Crassatellites alaeformis* and *Ostrea compressirostra* (Zone 8)	30
		Piscataway	Dark-colored greensand chiefly filled with broken shells of *Meretrix ovata* var. *pyga* *Crassatellites alaeformis* (Zone 7)	7
			Ditto, with same shells in whole condition (Zone 6)	1
			Indurated layer of light-colored greensand filled with *Turritella mortoni*, *T. humerosa*, *Crassatellites alaeformis*, *Dosiniopsis lenticularis* *Meretrix ovata* var. *pyga*, *Panopea elongata*, *Pholadomya marylandica* (Zone 5)	2
			Greensand marl containing same forms (Zone 4)	8
			Indurated layer of dark-colored greensand with *Crassatellites alaeformis*, *Meretrix ovata* var. *pyga*, *Dosiniopsis lenticularis*, and *Ostrea compressirostra* (Zone 3)	2
			Greensand marl with *Dosiniopsis lenticularis*, *Meretrix ovata* var. *pyga* and *Crassatellites alaeformis* (Zone 2)	16
			Total	112

II. *Section two miles up Aquia Creek.*

			Feet
		Gravel and sand	7
ia	Piscataway	Indurated greensand (Zone 3)	1
		Greensand with characteristic fossils (Zone 2)	15
		Argillaceous sand more or less glauconitic without fossils (Zone 1)	18
		Total	41

Section of western portion of bluff at Aquia Creek.

			Feet
		Fine sand, light-yellow in color, with white clay near the base	26
ia	Paspotansa	Fine sand, of light-greenish color, containing a few glauconitic grains (Zone 10)	10
		Thick-bedded, arenaceous, and glauconitic limestone interstratified with unconsolidated layers of partially weathered greensand, the indurated layers largely filled with the shells of *Turritella mortoni* (Zone 9)	10
		Fine sand, of gray or green color, containing several irregular bands of *Turritella mortoni*, also *T. humerosa*, *Cucullaea gigantea*, *Crassatellites alaeformis* and *Ostrea compressirostra* (Zone 8)	30
		Dark-colored greensand chiefly filled with broken shells of *Meretrix ovata* var. *pyga* *Crassatellites alaeformis* (Zone 7)	7
	Piscataway	Ditto, with same shells in whole condition (Zone 6)	1
		Indurated layer of light-colored greensand filled with *Turritella mortoni*, *T. humerosa*, *Crassatellites alaeformis*, *Dosiniopsis lenticularis* *Meretrix ovata* var. *pyga*, *Panopea elongata*, *Pholadomya marylandica* (Zone 5)	2
		Greensand marl containing same forms (Zone 4)	8
		Indurated layer of dark-colored greensand with *Crassatellites alaeformis*, *Meretrix ovata* var. *pyga*, *Dosiniopsis lenticularis*, and *Ostrea compressirostra* (Zone 3)	2
		Greensand marl with *Dosiniopsis lenticularis*, *Meretrix ovata* var. *pyga* and *Crassatellites alaeformis* (Zone 2)	16
		Total	112

Fig. 1.—Base of bluff at
formation.

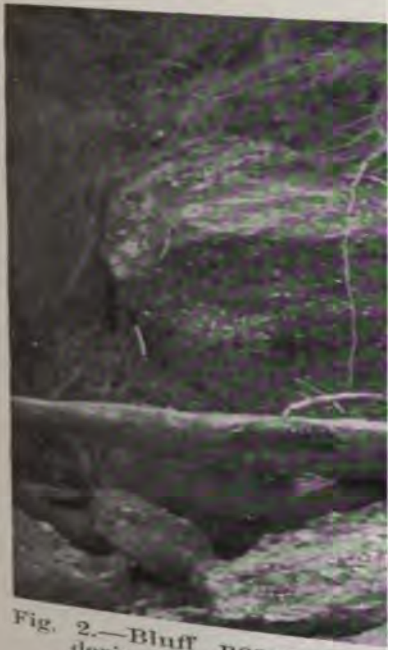

Fig. 2.—Bluff near mout
derived from zone 9 o
mortoni.

IV. *Section of center of bluff at Potomac Creek.*

				Feet
Pleistocene			Fine yellowish sand containing red and brown bands	15
Miocene			White gritty clay, with Miocene fossils at base	5
Eocene.	Nanjemoy	Potapaco	Greenish-gray argillaceous sand, slightly glauconitic (Zone 15)	38
			Argillaceous sand containing bands of selenite crystals (Zone 14)	4
			Light-gray glauconitic sand with *Venericardia potapacoensis* (Zone 13)	3
			Greenish-gray argillaceous sand (Zone 12)	8
			Indurated greensand with *Venericardia potapacoensis* (Zone 11)	1
			Greenish-gray argillaceous sand, glauconitic, with casts of *Meretrix* (Zone 10)	25
	Aquia	Paspotansa	Thick-bedded arenaceous and glauconitic limestone interstratified with layers of partially weathered greensand, the indurated strata largely composed of the shells of *Turritella mortoni* (Zone 9)	12
			Greensand bed, much weathered in its upper portions, and filled chiefly with *Turritella mortoni* in several thick layers; also *T. humerosa, Cucullaea gigantea, Crassatellites alaeformis, Ostrea compressirostra,* and many other species (Zone 8)	25
			Total	**136**

V. *Section on Potomac Run, near Potomac Church.*[a]

			Feet
Eocene.	**Aquia**	Very fine, loose, slightly argillaceous, yellow sand with imprints of shells sparingly shown	20
		Greenish-yellow and yellow, fine argillaceous sand, with many imprints of shells, especially in its lower portion forming a greensand marl	10
		Brownish-yellow sandy clay, spotted with white	4
		Dark gray clay, mottled with brown	5
		Gray argillaceous sand, with small pebbles	3
		Brownish sandy clay speckled and mottled with gray and white	3
		Thick mass, only partially exposed, of fine argillaceous and variegated incoherent sand	40
Lower Cretaceous.	Patapsco	Potomac cobblestone bed	3-4
		Friable reddish-brown sand	2½
		Dark-gray, coarse, somewhat argillaceous sand (exposed)	2-3
		Total	94½

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[a] Bull. U. S. Geol. Survey, No. 145, p. 76.

VI. *Section one and one-half miles southeast of Stafford.*

				Feet
Eocene.	Aquia	Paspotansa	Indurated limestone containing principally casts of fossils although in some instances portions of the shell substance remain. *Turritella mortoni* is very numerous and appears to be of the same horizon as that exposed at the mouth of Aquia Creek....	12

SECTIONS ON THE RAPPAHANNOCK RIVER.

The Aquia formation is well exposed along the Rappahannock River from a short distance below Fredericksburg to Hopyard Wharf. Just below the latter point it dips below tide level, disappearing beneath the overlying Nanjemoy deposits.

I. *Section left bank of Rappahannock River, opposite mouth of Massaponax Creek.*

			Feet
Pleistocene		Sand, gravel, etc. ....about	12
Eocene.	Aquia	Gray argillaceous sand mottled with yellow probably weathered Eocene greensand....	5
Lower Cretaceous.	Patuxent	Coarse arkosic sand and gravel containing angular clay pebbles up to 3 inches in diameter	20
		Total..............................	37

II. *Section right bank of Rappahannock River, one-half mile below mouth of Massaponax Creek.*

			Feet
Pleistocene		Concealed except 2 feet of gravel along base	20
Eocene.	Aquia	Dark greensand not well exposed except 3 feet at base. sharp contact with underlying bed	22
Lower Cretaceous.	Patuxent	Coarse gravelly compact arkosic sand......	12
		Total...............................	54

III. *Section right bank of Rappahannock River, one mile below mouth of Massaponax Creek.*

			Feet
Pleistocene		Yellow sand and gravel with boulders......	8
Eocene.	Aquia	Light greenish-gray glauconitic sand, probably dark green if not weathered........	17
		Similar materials full of fossils, *Crassatellites alaeformis, Cucullaea gigantea, Ostrea compressirostra, Meretrix ovata* var. *pyga, Turritella mortoni*, etc..................	12
		Dark green compact, finely micaceous greensand	15
		Total..............................	52

IV. *Section left bank of Rappahannock River, one and one-half miles below mouth of Massaponax Creek.*

			Feet
Pleistocene		Sand and gravel with boulders.............	8
Eocene.	Aquia	Dark greensand ....about	20
		Total..............................	28

V. *Section right bank of Rappahannock River three miles below mouth of Massaponax Creek.*

			Feet
Pleistocene		Yellow sand and gravel ....about	10
Eocene.	Aquia	Dark greensand more or less argillaceous, grading into clay at base. Fossil casts are present in lower 10 feet and especially abundant in lower 5 feet...............	35
		Total..............................	45

VI. *Section a few hundred yards below preceding section.*

			Feet
Pleistocene		Coarse sand and gravel containing boulders	8
		Fine-grained greenish-gray carbonaceous sand	5
		Yellow gravel with pebbles up to 3 or 4 inches in diameter	5½
Eocene.	Aquia	Dark green argillaceous finely micaceous sand	21
		(Irregular contact with offsets of as much as 2 feet suggest an unconformity but may be simply the irregular upper surface of marl lenses). Dark greensand full of fossils most of which are very fragile and soft, including *Ostrea compressirostra, Turritella mortoni, Meretrix ovata* var. *pyga* ?, *Crussatellites alaeformis, Modiolus alabamensis, Dosiniopsis lenticularis, Crassatellites sp.*............................	13
		Total..............................	52½

VII. *Section left bank Rappahannock River, one mile above mouth of Muddy Creek.*

		Feet
Pleistocene	Yellow sand and gravel	22
Eocene. Aquia	Dark green argillaceous sand lighter in color where weathered. No fossils	40
	Total	62

A half mile below the mouth of Muddy Creek, Aquia greensand is poorly exposed in the river bluff rising to a height of 10 feet above the water, while on the right bank of the river about 1½ miles below Muddy Creek light greenish-gray Aquia sand appears at the base of a 50-foot bluff. The greater portion of the bluff consists of Pleistocene sand and gravel.

VIII. *Section left bank of Rappahannock River one and one-quarter miles above the mouth of Ware Creek.*

		Feet
Pleistocene	Yellow sand and gravel with a line of large crystaline rock and quartz cobbles at base	28
	Greenish-gray, sandy clay and fine-grained stratified carbonaceous and argillaceous sand	14
	Band of coarse gravel with cobbles and boulders	2
Eocene. Aquia	Dark green, argillaceous sand with fossils principally *Turritella mortoni;* also *Crassatellites alaeformis, Modiolus alabamensis, Meretrix ovata, Ostrea compressirostra, Lunatia marylandica, Corbula aldrichi, Diplodonta hopkinsensis, Crassatellites sp.*	2
	Total	46

IX. *Section right bank of Rappahannock River just below mouth of Ware Creek.*

		Feet
Pleistocene	Not well exposed but principally composed of gravel and sand	20
Eocene. Aquia	Greenish-gray argillaceous sand. Fossils occur near the top of bed which is not well exposed. At the base there is a layer of shells containing numerous specimens of *Turritella mortoni.* Other species are the same as those in preceding section. Portions of this fossil layer are indurated	15
	Total	35

About one mile below the mouth of Ware Creek there is a 70-foot bluff on the right bank of the Rappahannock River apparently composed mainly of Aquia greensand.

X. *Section on Rappahannock River, Radcliffe's Wharf.*

		Feet
Pleistocene	Sand and gravel	14
Eocene. Aquia	Dark green argillaceous greensand. Fossils in lower 8 feet *Turritella mortoni*, *Crassatellites alaeformis*, *Meretrix ovata* (?), *Ostrea compressirostra*, *Lunatia marylandica*, *Modiolus alabamensis*, *Cucullaea gigantea* etc. *Turritella mortoni* is the most conspicuous fossil, being present in great numbers	17
	Total..............................	31

Just above Hopyard Wharf the Aquia formation outcrops for a distance of half a mile or more. It consists mainly of a bluish sandy clay carrying some greensand. Near the base of the cliff in many places the material is indurated, to form nodules 6 to 10 feet long and 2 to 4 feet in diameter that lie flat and project from the bluffs. Both the blue clay and its nodules contain many casts and some shells of *Turritella mortoni*. Other forms are rare.

SECTIONS ALONG MATTAPONI RIVER.

Along the Mattaponi River in Caroline County the Aquia formation is exposed in a few places. It probably forms a continuous bed underlying the valley from a point about three miles north of Milford where there is a poor exposure of dark green glauconitic sand to a short distance below the crossing of the road which leads from Penola to Shumansville.

I. *Section right bank of Mattaponi River, R. F. & P. R. R. bridge, four miles south of Milford.*

		Feet
Pleistocene	Yellow sand and gravel	10
Eocene. Aquia	Dark colored greensand indurated in places to form large concretions and containing *Turritella mortoni* in large numbers with *Meretrix ovata*, *Modiolus alabamiensis*, *Crassatellites alaeformis*, *Ostrea compressirostra*, etc.	10
	Total..............................	20

Between the point where the above section was taken and Milford, Aquia greensand containing fossil casts is poorly exposed in several places.

II. *Section right bank of Mattaponi River at first county bridge below R. F. & P. R. R. crossing.*

			Feet
Pleistocene		Concealed	8
Eocene.	**Aquia**	Dark colored greensand with casts of *Turritella mortoni* in a layer, 1 foot above water level, and with light drab clay lenses in upper part	5
		Total	13

SECTIONS ALONG PAMUNKEY RIVER.

The Aquia formation occurs as a continuous bed for a distance of many miles along the Pamunkey River. It is, however, less fossiliferous here than along the Potomac River.

I. *Section right bank of Pamunkey River on farm at Reformatory, about one and one-half miles southeast of Hanover Courthouse.*

			Feet
Pleistocene		Coarse yellow sands, cross-bedded, with occasional gravel layers	12 to 15
Eocene.	**Aquia**	Dark greenish-black micaceous sandy marl with many black grains of glauconite and a few shells	10
		Covered	6
		Total	31

II. *Section in small ravine about one-eighth mile southeast of Wickham.*

			Feet
Pleistocene		Concealed	3
		Coarse, yellowish-gray sand	6-8
Eocene.	**Aquia**	Dark green to greenish-black marl, highly fossiliferous, the shells being much decomposed, among them being *Turritella mortoni*, *Crassatellites alaeformis*, and *Ostrea compressirostra*	5
		Coarse gravel bed with pebbles from ½ inch to 4 inches thick and with dark greensand lenses	2+
		Total	18

III. *Section along river road about three and one-half miles southeast of Hanover Courthouse.*

			Feet
Pleistocene		Yellowish sands with gravel	4-6
		Drab clay with yellow streaks	6-8
		Compact yellow sandy clay	1-
Eocene.	**Aquia**	Weathered, incoherent, greensand, stained brown in places	3
		Total	18

IV. *Section along river road about four miles southeast of Hanover.*

			Feet
Pleistocene		Concealed	6
		Coarse yellow cross-bedded alternating sand and gravel layers with two layers of iron crusts at base between which is a very coarse gravel layer with large boulders of gneiss (1 to 2 feet in diameter). From this coarse gravel layer a stream issues	7
Eocene.	**Aquia**	Reddish-yellow weathered greensand marl with fossil impressions	1
		Dark green, glauconitic, micaceous, sandy clay with a few fossils, a small *Venericardia* being most abundant	15
		Total	29

V. *Section right bank Pamunkey River about seven miles southeast of Hanover Courthouse and two and one-half miles from Studley.*

			Feet
Pleistocene		Yellow sand and gravel	15
Eocene.	**Aquia**	Dark green glauconitic sand, coarse in lower portion and fine in upper, containing fossil impressions	4
		Layer of small dark-colored gravels, sharks teeth and bone fragments	2-3 in.
		Dark green glauconitic micaceous sandy marl with a few fossils	12
		Concealed	15
		Total	46 3 in.

A similar section is exposed on the right bank of the Pamunkey River about five miles northeast of Studley.

SECTIONS ALONG CHICKAHOMINY RIVER.

The Aquia formation has not thus far been observed along the Chickahominy River, but this is undoubtedly due to its being concealed from view by the recent swamp deposits that are so extensively developed in the river valley.

SECTIONS ALONG JAMES RIVER.

The Aquia formation is exposed at a number of localities in the James River valley from Richmond to City Point where it disappears beneath water level. It is by no means continuous between these points as most of the bluffs show Patuxent strata immediately overlain by Pleistocene sands and gravels. Also in one place the Piedmont crystalline rocks come to the surface. The deposits consist almost entirely of glauconitic sand in which are occasional fossil casts although they are seldom abundant and in this respect form a striking contrast to the Aquia deposits exposed along the Potomac River.

In Richmond the Aquia is exposed in many places along Shockoe and Gillis creeks. A short distance south of the Locomotive Works a thickness of about 8 feet of Aquia is exposed and here it consists of a greenish-gray fine sand somewhat resembling in color a mixture of pepper and salt. It is overlain by impure diatomaceous earth belonging to the Calvert formation. The Aquia sand contains some glauconite though much less than occurs at most places. In the sand are numerous sharks teeth, fragments of bones, and a very few molluscan casts. Along Gillis Creek in the southeast portion of Richmond the Eocene is exposed in several places and the weathered greensand has been dug for use as moulding sand. It contains a few small pebbles and fossil casts.

I. *Section at Howlett House Bluff, right bank of James River, three and one-half miles east of Chester.*

			Feet
Pleistocene.	Sunderland	Yellow loam grading downward into mottled (red, drab, yellow) loam and then into coarse brown sand with few pebbles....	45
Miocene.	Calvert	Yellow sand, very fine, formerly shipped away in barges as a moulding sand. Upper part coarser than lower.................	35
		Compact clay, blue when fresh, pure white when dry	15
Eocene.	Aquia	Mottled light and dark grayish-green sand with considerable glauconite.............	15
Lower Cretaceous.	Patuxent	Conglomerate bed containing large and small cobbles, pebbles, etc., in matrix of coarse arkosic sand. Materials extremely variable. Lower part is in several places quite firmly indurated (exposed to water's edge)....	30
		Total...............................	140

II. *Section on James River, five miles above City Point.*

The Aquia formation outcrops above the water to a height of from 1 to 9 feet for a distance of about one-half to three-quarters of a mile above upper Shirley. It consists of dark, almost black, fine, argillaceous sand containing small pieces of mica and some casts of *Turritella mortoni* and pelecypods. The upper part where weathered is yellow.

SECTIONS ALONG NOTTOWAY RIVER.

The most southerly exposures of Eocene strata in Virginia occur near Bolling's Bridge on the Nottoway River where McGee[a] first reported the presence of three or four feet of dark-colored clay containing Eocene fossils. In the absence of any characteristic species this material is referred to the Aquia formation. It occurs in immediate contact with Potomac strata.

The Nanjemoy Formation.

Name and areal distribution.—This formation has been so named because of the excellent exposures of beds of this age along the Nanjemoy Creek, a stream flowing into the Potomac River from the Maryland side. The name was proposed by Clark and Martin in 1901.[b]

Stratigraphic relations.—The stratigraphic relations of the Nanjemoy formation are very simple. The formation rests conformably upon the Aquia, while it is covered by the deposits of the Calvert formation with which it is unconformable. The Calvert transgresses the Nanjemoy altogether in northeastern Maryland and probably also in southern Virginia, so that it comes to rest directly upon the Aquia, the Nanjemoy not appearing at the surface. It probably underlies the Calvert, however, throughout the entire eastern portion of the State. In certain places near the outcrop of the formation the Nanjemoy deposits are unconformably overlain by the unconsolidated materials of the Pleistocene.

Lithologic character.—The Nanjemoy formation is composed of greensand, often highly argillaceous and less frequently calcareous than the Aquia deposits, and with here and there layers containing abundant crystals and crystalline masses of gypsum. The base of the Nanjemoy is usually marked by a bed of compact white and pink clay resting directly upon the greensand of the Aquia. This clay bed forms a very persistent layer which has received the name of Marlboro clay from Marlboro, Maryland, where it is well exposed.

Strike, dip, and thickness.—The strike of the Nanjemoy is almost due north and south, while the beds dip to the east at the rate of from 12 to 15 feet to the mile. In the deep wells in the vicinity of Norfolk the Nanjemoy is reached at the depth of about 600 feet. The thickness where all the beds are developed is about 125 feet. It generally thins somewhat to the westward, as in the case of most of the Coastal Plain formations.

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[a] Amer. Jour. Sci., vol. xxxv, 1888, p. 126.

[b] Eocene, Maryland Geological Survey, p. 64.

Division.—The Nanjemoy formation has been divided into two members known as the *Potopaco* clay member and *Woodstock* greensand marl member, the former having a thickness of from 60 to 65 feet and the latter from 50 to 60 feet. The Potopaco member is composed of greensand, often very argillaceous and at times gypseous. The clayey character of this member especially in its lower portions is in marked contrast to the more highly glauconitic beds of the Aquia formation below. The Woodstock member is characterized by fine homogeneous greensands and greensand marls that are much less argillaceous than the underlying Potopaco beds. The Potopaco member in the Potomac region is subdivided into six zones and the Woodstock member into two zones. The two members show paleontological differences to which reference will be made again later.

Paleontologic character.—The fossils of the Nanjemoy are not quite so plentiful as in the Aquia formation yet locally they are very abundant. All of the chief groups of the invertebrates are represented, as well as fishes, and a few plant remains. The latter consist of some small lignitized nuts found along the Potomac River near Popes Creek, Maryland. In 1850 a fossil nut the size of a large hickory nut was described by Ruffin, from the Eocene of the Pamunkey, probably from the Nanjemoy. As in the case of the Aquia, the molluscs predominate. The most widely distributed and abundant form is *Venericardia potapacoensis,* it being found in almost every exposure of Nanjemoy greensand.

Among the forms which are limited to the Nanjemoy formation but found in both members are:

Meretrix ovata var. *ovata* (Rogers)
Lucina dartoni Clark
Lucina whitei Clark
Venericardia potapocoensis Clark & Martin
Ostrea sellaeformis Conrad
Leda improcera (Conrad)
Leda potomacensis Clark & Martin
Leda tysoni Clark & Martin
Nucula potomacensis Clark & Martin

The following species have been found only in the Potopaco member:

Cypraea smithi Aldrich
Solen lisbonensis Aldrich
(?) *Lucina astartiformis* Aldrich
Periploma sp.
Ceriopora micropora Goldfuss

The following species among others are found only in the Woodstock member:

Galeocerdo latidens Agassiz
Levifusus trabeatus (?) Conrad
Pyrula penita Conrad var.
Turritella potomacensis Clark & Martin
Dentalium minutistriatum Gabb
Meretrix lenis (Conrad)
Venericardia marylandica Clark & Martin
Modiolus marylandicus Clark & Martin
Leda parva (Rogers)
Carpolithus marylandicus Hollick

Areal distribution.—The Nanjemoy formation outcrops along a narrow belt to the east of the Aquia formation. It is well exposed where the Aquia disappears beneath tide. The Nanjemoy is also exposed in the lower courses of most of the tributary streams flowing into the Potomac and Rappahannock rivers in the eastern part of King George and Caroline counties, along the Pamunkey River between King William and Hanover counties, and along the James River in the vicinity of City Point. The upper surface of the Nanjemoy disappears below tide just below Mathias Point on the Potomac, a short distance below Port Royal on the Rappahannock, and at the mouth of Powells Creek, about seven miles below City Point on the James River. The Nanjemoy has not been recognized on the Nottoway River.

DETAILED SECTIONS.

SECTIONS ALONG POTOMAC RIVER.

The sections of the Nanjemoy formation exposed along the Potomac River and its tributaries are among the best to be found in the State. They occur in King George County where the current of the river is deflected against the Virginia shore on account of the river turning sharply to the left at this point. Prominent bluffs result from the erosive action of the water and in these bluffs are many good exposures of Nanjemoy strata. At Mathias Point the river turns somewhat less abruptly to the right and high bluffs have been formed on the Maryland shore near Pope's Creek. A few sections from near that place are included to show the characteristics of the entire formation along the valley of the Potomac River.

I. *Section on the south side of Potomac Creek, about one and one-half miles east of the railroad.*

				Feet
Eocene.	Nanjemoy	Potapaco	Gray sand with some glauconite, and a few casts	12
			Very compact white clay blotched with limonite stains	7
			Compact pink clay, no fossils	17
	Aquia	Paspotansa	Glauconitic sand with occasional layers of fossil casts	30
			Total	66

II. *Section right bank of Potomac River three miles below Potomac Creek.*

				Feet
Pleistocene			Sand and gravel	2
Eocene.	Nanjemoy	Potapaco	Greenish-gray argillaceous sand (Zone 15)	4
			Greenish-gray argillaceous sand with gypsum crystals (Zone 14)	5
			Light gray greensand with band containing *Venericardia potapacoensis* (Zone 13)	4
			Greenish-gray argillaceous sand (Zone 12)	10
			Indurated greensand with *Venericardia potapacoensis* (Zone 11)	1
			Total	26

III. *Section right bank of Potomac River, center of bluff at Woodstock.*

				Feet
Pleistocene			Yellow and orange-colored sands and gravel	25
Miocene.	Calvert		Diatomaceous earth with Miocene fossils	5
Eocene.	Nanjemoy	Woodstock	Argillaceous greensand (Zone 17	6
			Dark greensand more or less argillaceous with *Mitra potomacensis, Mesalia obruta, Strepsidura subscalarina, Turritella potomacensis, Corbula oniscus, Meretrix subimpressa, Protocardia lenis, Pecten dalli, Ostrea sellaeformis, Glycymeris idoneus* and *Leda cultelliformis* (Zone 16)	20
		Potapaco	Greensand with *Tornatellaea bella, Cylichna venusta, Ringicula dalli, Venericardia potapacoensis* and other forms (Zone 15)	6
			Total	62

IV. *Section two miles west of Passapatanzy, along hillside.*

			Feet
Pleistocene		Gravel and loam	10
Miocene.	Calvert	Diatomaceous earth	25
		Blue and drab clay with a few fossil impressions	6
Eocene.	Nanjemoy	Greensand, exposed	3
		Total	44

V. *Section left bank of Potomac River, three miles above Pope's Creek.*

				Feet
Pleistocene			Gravel and sand	3
Eocene.	Nanjemoy	Potapaco	Argillaceous greensand (Zone 15)	6
			Greensand with gypsum crystals (Zone 14)	5
			Total	14

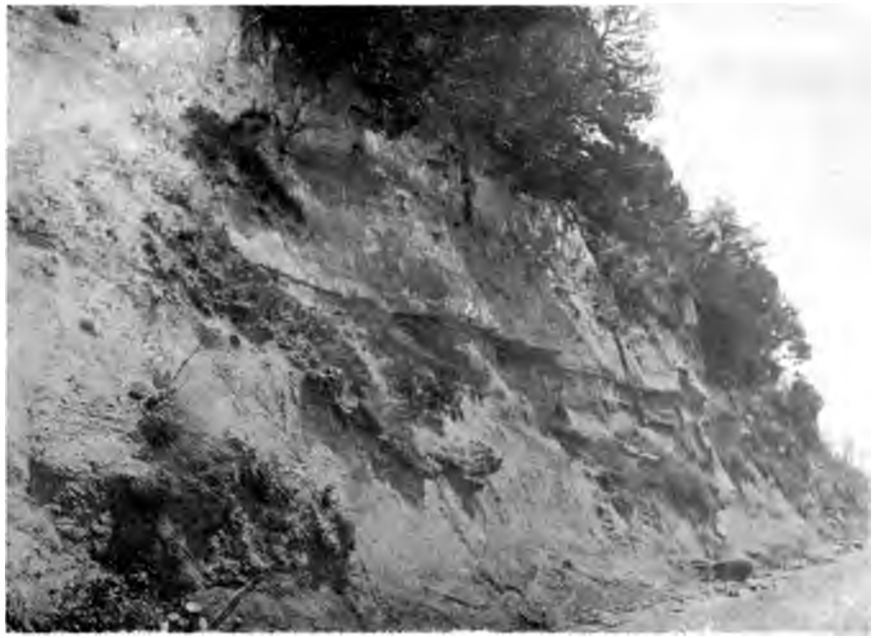

Fig. 1.—Bluff at Popes Creek, Potomac River, Maryland, showing zone 17 of Nanjemoy formation overlain by diatomaceous earth beds of Calvert formation.

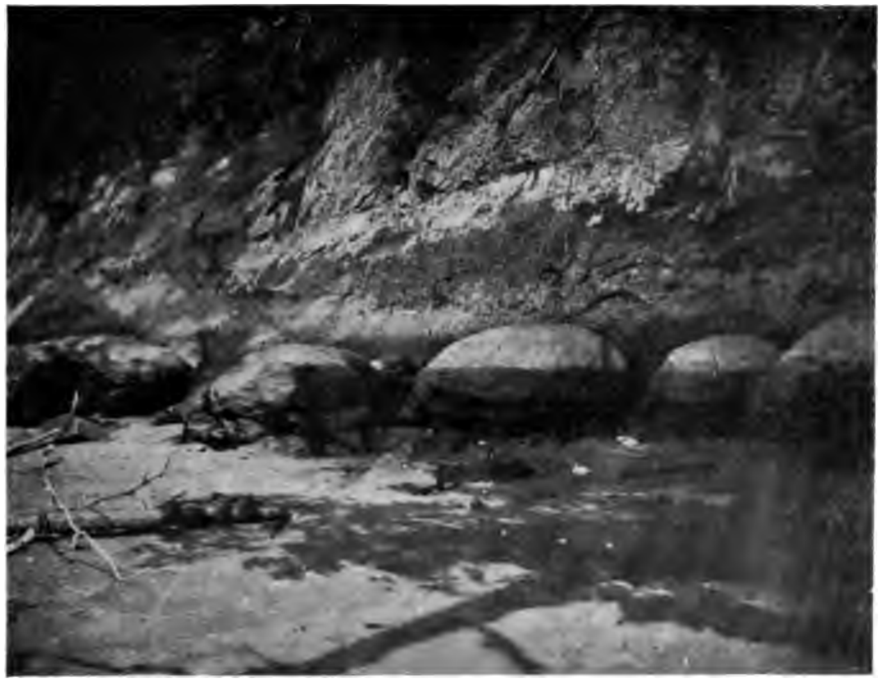

Fig. 2.—Bluff at Hopyard, Rappahannock River. Showing calcareous concretions of Aquia formation.

NANJEMOY AND AQUIA FORMATIONS.

VI. *Section left bank of Potomac River two and one-quarter miles above Pope's Creek, Md.*

			Feet
Miocene. Calvert		Diatomaceous earth	10
Eocene. Nanjemoy	Woodstock	Greensand with fossil casts (Zone 17)	10
		Greensand, somewhat argillaceous (Zone 10)	30
	Potapaco	Grayish black argillaceous greensand (Zone 15) with numerous bands of *Venericardia potapacoensis* and other fossils, overlain by a band of concretions	5
		Total	55

VII. *Section of bluff left bank of Potomac River, one mile below Pope's Creek, Md.*

			Feet	Inches
Miocene. Calvert		Diatomaceous earth	40	
Eocene. Nanjemoy	Woodstock	Brown glauconitic clay much oxidized in places	2	
		Band of pinkish-brown clay nodules in glauconitic clay	0	6
		Dark glauconitic clay with many fossil casts	4	
		Concretions with occasional fossils	0	6
		Argillaceous greensand with many casts and occasional shells	3	
		Concretions with many large specimens of *Hercoglossa tuomeyi*	0	6
		Argillaceous greensand with abundant fossils including *Meretrix subimpressa*, *Venericardia potapacoensis*, *Hercoglossa tuomeyi*, *Turritella potomacensis*, *Mesalia obruta*, *Protocardia lenis*, *Modiolus alabamensis*, *Corbula subengonata*, *Mitra potomacensis*, and many other forms (Zone 17)	6	
		Total	56	6

SECTIONS IN THE RAPPAHANNOCK RIVER VALLEY.

The Nanjemoy formation is exposed in many places along the Rappahannock River. The finest exposures are in those places where the river in its meanders cuts into the valley bluffs. In such places the bluffs are high and the Nanjemoy strata well exposed in a few places, although the covering of vegetation and the landslides occasionally conceal the undisturbed strata.

In a cut on the R. F. & P. R. R. between Potomac Creek and Rappahannock River about 3½ miles north of Fredericksburg, there is an exposure of Nanjemoy and Aquia strata. At the south end of the cut a few feet of Potomac arkosic sand appears overlain by Eocene greensand. In the centre of the cut the Nanjemoy clay is exposed. At a few places along the base the Eocene is dark green and unweathered but for the most part it is weathered to lighter shades, and more or less mottled with buff. The cut is about 35 feet deep.

I. *Section left bank of Rappahannock River at Hopyard.*

			Feet
Pleistocene		Yellow sand and gravel	12
Eocene.	Nanjemoy and Aquia	Argillaceous greensand	35-40
		Total	52
		Above the wharf the upper part of the bluff is not well exposed. Near the base the following Aquia fossils were obtained: *Turritella mortoni*, *Arca* (?), *Crassatellites*, *Meretrix*, *Ostrea compressirostra*, *Corbula*. Below the wharf a few hundred yards and near the top of the Eocene several thin layers of Nanjemoy fossils occur. The principal form is *Venericardia potapacoensis*. This is the first appearance of the Nanjemoy formation on the Rappahannock River. The fossiliferous material is a clay rather than a sand although it is somewhat arenaceous. Many of the shells in this place are waterworn.	

II. *Section right bank of Rappahannock River, two and one-half miles below Hopyard.*

Eocene.	Nanjemoy and Aquia	The bluff is about 40 to 50 feet high. Not well exposed except near base where about 10 feet of fossiliferous Eocene greensand outcrops in which are *Turritella mortoni*, *Meretrix subimpressa*, *Crassatellites alaeformis* and *Lunatia marylandica*. The Nanjemoy is undoubtedly present in the concealed portion of the bluff.

III. *Section right bank of Rappahannock River one and one-half miles below the mouth of Mount Creek.*

			Feet
Pleistocene		Coarse yellow sand and gravel	30
Eocene.	Nanjemoy	Dark green finely arenaceous and micaceous clay. Fossils occur in the lower 6 feet. *Venericardia potapacoensis*, *Meretrix subimpressa*, *Corbula oniscus* are abundant. The fossils are broken and water-worn and in this respect resemble the layer at Hopyard containing *Venericardia potapacoensis*. It is probably the same horizon	18
		Total	48

On the left bank of the Rappahannock River two and one-half miles above Port Conway, in a bluff 25 to 30 feet in height, some weathered greensand is exposed near the base. The greater portion of the bluff consists of Pleistocene materials.

IV. *Section left bank of Rappahannock River, about three-quarters of a mile above Port Conway.*

			Feet
Pleistocene		Sand, gravel, etc., not well exposed, about..	15
Eocene.	**Nanjemoy**	Dark green arenaceous glauconitic clay. Fossils especially in bed 4 feet thick at base of cliff and in a band 12 to 16 feet above base. The fossils in the lower stratum are as follows: *Venericardia potapacoensis*, *Corbula oniscus*, *Meretrix lenis?* *Ostrea Venercardia*, *sp.*, *Meretrix ovata*, *Turbonilla potomacensis*, etc. The fossils from the upper zone are *Venericardia potapacoensis*, *Meretrix*, *Turritella*, etc.	25
		Total..............................	40

The Nanjemoy formation outcrops just above Port Conway for a distance of about three-quarters of a mile. In some places it extends to a height of 18 feet above the water. It consists of a compact argillaceous greensand with a few layers of fragile shells principally *Venericardia potapacoensis*. On the Port Royal side the Nanjemoy also outcrops in the river bluff but the exposed thickness is not more than 10 or 12 feet. Shell layers here consist mainly of *Venericardia potapacoensis* and *Turritella* sp. Pleistocene materials overlie the Nanjemoy strata on both sides of the river.

On the south bank of the Rappahannock River between Port Royal and the mouth of Mill Creek, Nanjemoy greensand is poorly exposed in several places.

V. *Section left bank of Rappahannock River two miles below Port Conway.*

			Feet
Pleistocene		Sand and gravel...........................	12
Eocene.	**Nanjemoy**	Dark argillaceous greensand containing fossils at base.................................	10
		Total...............................	22

VI. *Section left bank of Rappahannock River three-quarters of a mile east of the mouth of Jetts Creek.*

			Feet
Pleistocene		Sand and gravel	10
Eocene.	Nanjemoy	Argillaceous greensand more or less weathered. Contains a few casts, among which are specimens of *Corbula aldrichi*	20
		Total	30

SECTIONS IN THE MATTAPONI RIVER VALLEY.

Along the Mattaponi River the Nanjemoy is exposed at the base of the bluffs for a considerable distance with the upper portion of the bluffs composed of diatomaceous earth or blue argillaceous sand belonging to the Calvert formation. This line of contact, although undulating, is far more regular than one would expect to find, for an extensive erosion interval separates the two formations. The contact is usually about 15 to 20 feet above the level of the water in the river.

I. *Section left bank of Mattaponi River about one-half mile below crossing of the County road leading from Penola to Shumansville.*

			Feet
Pleistocene		Sand and gravel, not well exposed	8-10
Eocene.	Nanjemoy	Dark, compact greensand containing casts of *Venericardia potapocoensis*	1½
	Aquia	Glauconitic sand separated from the overlying bed by a ferruginous sand layer	6½
		Total	18

II. *Section left bank of Mattaponi River three or four miles below the preceding locality.*

A terrace, about 45 feet above the river level comes close to the river at this point. There is no good section in the river bluff but by following a short distance up a ravine the following imperfect section was observed.

			Feet
Pleistocene (?)		Concealed about	20
Miocene.	Calvert	Olive green or greenish-gray sandy clay. . about	18
Eocene.	Nanjemoy	Compact greensand about	7
		Total	45

A fairly good exposure of the Calvert-Nanjemoy contact was seen at one place, where it was sharp and decidedly undulating.

About 1½ miles below the preceding, the greensand appears at the base of a 15-foot terrace. The exposure is a few rods back from the river bank. This locality is about one-half mile below the mouth of Pole Cat Creek.

III. *Section left bank of Mattaponi River about one-half mile below the preceding, one-half mile above Burke's Bridge.*

			Feet
Pleistocene (?)		Concealed	14
Eocene.	Nanjemoy	Compact greensand with impressions of *Venericardia potapacoensis*	12
		Total	26

At Burke's Bridge and for several miles below, Eocene greensand is occasionally seen at the base of a 15 or 20-foot terrace.

IV. *Section left bank of Mattaponi River three or four miles below Burke's Bridge.*

			Feet
Pleistocene		Concealed	8 or 10
Eocene.	Nanjemoy	Compact greensand containing fossils in lower 2 feet. Principal fossil is *Venericardia potapacoensis*. A few other small pelecypods are present	8
		Total	18

For several miles below the preceding locality Eocene greensand appears at the base of low sections rising in places to about 10 feet above the water. At a point between 6 and 8 miles below Burke's Bridge the river strikes a high upland. When it first touches it the slope is concealed by vegetation but about one-quarter mile below this point the following section could be made out, although the exposure is very poor.

V. *Section Mattaponi River eight miles below Burke's Bridge and one and one-half miles above Reedy's Mill Bridge.*

			Feet
Pleistocene (?)		Concealed about	22
Miocene.	Calvert	In the upper part 10 or 15 feet of greenish clay with casts of *Turritella plebeia* and in the lower part 6 or 8 feet of grayish argillaceous sand with a 1-foot gravel band along base containing quartz and phosphate pebbles and sharks teeth. The pebbles are all small	30
Eocene.	Nanjemoy	Grayish glauconitic sand	5
		Concealed	23
		Total	80

Eocene greensand appears at the base of low sections for the first 1½ miles below Reedy's Mill Bridge. The river then impinges on the upland on the left and the following section is exposed.

VI. *Section left bank of Mattaponi River, one and one-half miles below Reedy's Mill Bridge.*

			Feet
Pleistocene (?)		Concealed	20
Miocene.	Calvert	Greenish clay with casts of *Turritella;* impure diatomaceous earth in lower part	24
		Greenish argillaceous sand consisting principally of reworked Eocene greensand with a thin band of quartz pebbles, phosphate pebbles, sharks teeth, and pieces of bones more or less water-worn at base	10
Eocene.	Nanjemoy	Greensand with some pelecypod casts	26
		Total	80

VII. *Section left bank of Mattaponi River two and one-half or three miles below Reedy's Mill Bridge.*

			Feet
Pleistocene		Concealed except gravel band at base	11
Eocene.	Nanjemoy	Dark green arenaceous glauconitic clay with a band of water-worn fossils near the base; ***Venericardia potapacoensis*** abundant; also ***Pecten***, *Ostrea*, *Meretrix*, etc	10
		Total	21

About 4½ or 5 miles below Reedy's Mill Bridge a few Nanjemoy fossils, principally *Venericardia potapacoensis,* were collected in a section similar to the preceding. From the preceding locality to the mouth of Marricossick Creek, a distance of about 5 miles, Nanjemoy greensand and dark green clay continue to form the base of low sections. At one point a few miles above the mouth of the creek on the right the upland is washed by the river. The high river bluff resulting is not well exposed but 30 or 40 feet above the base greenish Miocene clays were observed, containing casts of *Turritella plebeia.*

VIII. *Section on Mattaponi River at the mouth of Marricossick Creek.*

			Feet
Pleistocene		Sand and gravel	4
Eocene.	Nanjemoy	Dark green argillaceous greensand	12
		Total	16

About two miles below the mouth of Marricossick Creek the river touches the base of a high upland rising 100 feet or more above the water level. The bluff is overgrown with vegetation to such an extent that only about 8 feet of Eocene greensand is exposed at the base. A number of fossils are present in this basal bed, among them being *Venericardia potapacoensis,* a number of small pelecypods, and some gastropods.

From the mouth of Marricossick Creek to the first county bridge below, a distance of about 5 miles, the Eocene greensand continues to appear at the base of a Pleistocene terrace. Not far above the bridge the Nanjemoy strata rise as much as 15 feet above the level of the water. On the left near the end of the bridge the road ascends a scarp some 25 or 30 feet above the river level. Toward the top light-colored clays of the Calvert formation are poorly exposed in the road.

IX. *Section right bank of Mattaponi River, eleven miles below mouth of Marricossick Creek.*

			Feet
Pleistocene		Sand and gravel	8
Miocene.	Calvert	Dark greenish clay at top grading downward into greenish argillaceous sand which has been derived from the Eocene and reworked. Along the base a thin band of gravel consisting of quartz and phosphate pebbles, etc., occurs	23
Eocene.	Nanjemoy	Greensand	4
		Total	35

About three miles below the preceding locality, a very similar section occurs on the left bank of the river, the chief difference being that only one foot of Nanjemoy materials appears at the base.

X. *Section Mattaponi River, about fifteen and one-half miles below the mouth of Marricossick Creek.*

			Feet
Pleistocene		Sand and gravel	5
Miocene.	Calvert	Greenish sandy clay	8½
Eocene.	Nanjemoy	Greenish arenaceous clay	1½
		Total	15

SECTIONS IN THE PAMUNKEY RIVER VALLEY.

The Nanjemoy formation outcrops along the Pamunkey River in many places although good exposures of the strata are few in number.

I. *Section right bank of Pamunkey River at Newcastle about one mile by road above Newcastle Bridge.*

			Feet
Pleistocene		Coarse yellow sand with small gravel	5
Eocene.	Nanjemoy	Coarse gray calcareous sandy marl containing small pebbles, glauconitic sand grains, and occasional fossiliferous layers. Among the fossil forms observed were *Venericardia* and *Ostrea sellaeformis*	7
		Concealed	12
		Total	24

At a spring just west of Newcastle Bridge on Pamunkey River at bend in the river the gray calcareous Nanjemoy marl similar to that at Newcastle outcrops. Above it is a heavy bed of reddish-yellow sand 12 to 15 feet thick.

About a mile east of Newcastle Bridge on the River Road, the Nanjemoy outcrops in the road. It is similar to that at Newcastle and contains similar fossils. Above it, there was found a coarse greensand layer with sharks teeth, bones and gravel at its base. This seems to belong to the Calvert formation and represents material derived from the Nanjemoy and reworked by the ocean waves during Miocene time.

On the right bank of the Pamunkey River at "Farmington," about one mile from Apperson's store and about three-quarters of a mile east of Newcastle Bridge, 6 feet of gray calcareous sandy marl containing glauconite similar to that at Newcastle is exposed at the base of a high bluff.

II. *Section right bank of Pamunkey River at mouth of Matadequin Creek.*

At this point marl works were established some years ago and the greensand marl dug, sifted, and sold as a fertilizer. The section is as follows:

			Feet
Pleistocene		Light colored yellow sand....................	4
Miocene.	Calvert	White friable sandy clay with fine gravel, fossil casts, and sharks teeth....................	6
		Olive green compact sandy clay stained brown in places..................................	4-6
		Layer of small gravel containing bones and sharks teeth..............................	2 in.
Eocene.	Nanjemoy	Dark green, glauconitic, sandy marl (exposed)	2-3
		Total................................	19+

SECTIONS IN THE JAMES RIVER VALLEY.

The Nanjemoy formation has a very limited distribution along the James River and there are few good exposures. The formation has not been recognized south of the James and probably does not extend much farther south. It is not exposed along the Nottoway or Meherrin rivers and is positively known to be absent in the Roanoke River valley. The formation in its most southerly exposures has not lost its typical characteristics as the following sections will show, but instead resembles the Nanjemoy strata of Maryland even more than those of the Pamunkey River valley.

I. *Section right bank of James River, two miles below City Point.*

			Feet
Pleistocene		Loam with gravels at base....................	8
Miocene.	Calvert	Shell marl, shells in buff to gray sand; common species are *Chama*, *Ecphora*, *Venus*, *Pecten*, *Perna*, *Crucibulum* *Crepidula*, *Oliva*, *Discinisca*, *Ostrea*, etc.	5
		Poor exposure, seems to be sand without fossils	7
		Shell bed, similar to above except without *Ecphora*, *Discinisca*, *Oliva* and *Perna*......	4
Eocene.	Nanjemoy	Marlboro pink to white to drab clay, very compact	3-5
	Aquia (?)	Glauconitic sand containing much gypsum, in places exposed to water................	15
		Total..............................	44

On the right bank of the James River, two and three-quarters miles below City Point greensand marl was formerly dug, dried and shipped to fertilizer factories. The section is about the same as that at the preceding locality. The Eocene greensand is directly overlain by Miocene shell marl and no diatomaceous earth appears. The Pleistocene is thicker, however. and the bluff higher than in the section given above. The marl was dug at this place for about twelve years, but in 1906 a great piece of the bank slid down and crushed the mill and covered up the pits, since which time the plant has been abandoned.

II. *Section right bank of James River, just below Indian Field Point, six miles below City Point.*

			Feet
Pleistocene		Buff to brown loose sand with a thick bed of pebbles near base not well exposed	25
		Bluff concealed by vegetation and by landslides	15
Miocene.	Calvert	Thin band of Miocene shell marl in buff sand matrix, whole layer somewhat disturbed as the result of landslides. *Arca centenaria* was the only perfect fossil observed	3
Eocene.	Nanjemoy	Shell layer, many rotten shells and great numbers of *Ostrea sellaeformis*	2
		Glauconitic sand, decidedly argillaceous, mainly concealed by vegatation to water's edge, formerly dug for fertilizing material	30
		Total	75

All along the river in this section there have been great landslides that have formed a distinct terrace which is now cultivated. The terrace is from 25 to 75 yards wide.

III. *Section right bank of James River at Coggins Point, nine miles below City Point.*

			Feet
Pleistocene		Coarse sand containing many pebble lenses	20
		Pebble and cobble band	10-15
Eocene.	Nanjemoy	Clay mottled, exposed	4
		Concealed by vegetation to water	18-20
		Total	59

TABLE SHOWING THE DISTRIBUTION OF THE EOCENE FAUNA.

SPECIES.	AQUIA FORMATION.																													
	POTOMAC RIVER.																	RAPPAHANNOCK RIVER.							MATTAPONI RIVER.		PAMUNKEY RIVER.	JAMES RIVER.		
	Fort Washington.	Tinkers Creek, near Piscataway.	1 mile N. E. of Piscataway.	Piscataway Creek.	Swan Creek, near Piscataway.	Pomonkey Neck.	Glymont.	1 mile S. E. of Mason Springs.	Mattawoman Creek.	Reedy Run.	Liverpool Point.	Wades Bay.	Clifton Beach.	Aquia Creek.	Potomac Creek.	Paspotansa Creek.	2 miles below Potomac Creek.	1 mile below Massaponax Creek.	3 miles below Massaponax Creek.	1¼ mile above Ware Creek.	Radcliffe's Wharf.	Above Hopyard Wharf.	2½ miles below Hopyard Wharf.	Near Brooke.	Mattaponi River, R. F. and P. R. R. Bridge.	Mattaponi River, first county bridge below R. R.	Pamunkey River, ⅛ mile S. E. of Wickham.	James River, Richmond.	James River, Deep Bottom.	James River, City Point.
REPTILIA.																														
psa sp.											●		●																	
psa contusor Cope														●																
psa marylandica Clark													●																	
? *sp.*													●																	
irginiana Clark														●																
PISCES.																														
copeanus Clark							●				●		●	●	●															
arcuatus Agassiz							●							●																
s clarkii Eastman								●			●																			
elegans (Agassiz)	●										●			●																
macrota (Agassiz)	●									●				●																
cuspidata (Agassiz)	●								●		●																			
liquus Agassiz							●				●			●																
n auriculatus (Bln.)																														
latidens Agassiz																														
risca Agassiz											●																			
radiata (Clark)													●																	
THROPODA. Ostracoda.																														
perarcuata Ulrich															●															
LLUSCA. Cephalopoda.																														
a tuomeyi C. & M.													●																	
LLUSCA. Gastropoda.																														
ea bella Conrad			●											●	●															
dalli Clark																														
enusta Clark			●					●					●		●		●													
a harrisi Clark								●							●		●													
a potomacensis C. & M.			●														●													
s ducateli C. & M.								●																						
a childreni Lea								●									●													
a piscatavensis C. & M.			●																											
a tysoni C. & M.								●																						
bellistriata Clark															●															
a sp.															●		●													
a graciloides Ald. *var.*								●																						
a potomacensis C. & M.								●																						
p.																														
s sp.														●	●															
pyruloides ? (Conrad)											●			●	●															
rylandica ? Clark						●																								
munkensis C. & M.			●			●									●		●													

TABLE SHOWING THE DISTRIBUTION OF THE EOCENE FAUNA.

SPECIES.	Nanjemoy Formation.																					
	POTOMAC RIVER.									RAPPAHANNOCK RIVER.			MATTAPONI RIVER.								PAMUNKEY RIVER.	
	Potomac Creek.	Nanjemoy Creek.	½ mile below Chapel Point.	2½ miles above Popes Creek.	Woodstock. Zone 15.	2 miles above Popes Creek.	1½ mile above Popes Creek.	Popes Creek.	Woodstock. Zones 16 and 17.	Rappahannock River, Hopyard.	1½ mile below Mount Creek.	¾ mile above Port Conway.	2 miles below Port Conway.	Mattaponi River, ½ mile below county bridge to Penola.	½ mile above Burke's Bridge.	3 to 4 miles below Burke's Bridge.	2½ miles below Reedy's Mill Bridge.	4¾ miles below Reedy's Mill Bridge.	2 miles below Marricossick Creek.	3 miles below Marricossick Creek.	Pamunkey River, Newcastle.	Pamunkey River, 1 mile east of Newcastle.
REPTILIA.																						
Thecachampsa sp.																						
Thecachampsa contusor Cope																						
Thecachampsa marylandica Clark																						
Euclastes ? sp.																						
Trionyx virginiana Clark																						
PISCES.																						
Myliobatis copeanus Clark									•													
Aetobatis arcuatus Agassiz								•														
Synechodus clarkii Eastman																						
Odontaspis elegans (Agassiz)																						
Odontaspis macrota (Agassiz)									•													
Odontaspis cuspidata (Agassiz)								•	•													
Otodus obliquus Agassiz																						
Carcharodon auriculatus (Bln.)								•														
Galeocerdo latidens Agassiz									•													
Sphyrna prisca Agassiz																						
Xiphias ? radiata (Clark)																						
ARTHROPODA. Ostracoda.																						
Cytheridea perarcuata Ulrich									•													
MOLLUSCA. Cephalopoda.																						
Hercoglossa tuomeyi C. & M.								•														
MOLLUSCA. Gastropoda.																						
Tornatellaea bella Conrad					•				?													
Ringicula dalli Clark									•													
Cylichna venusta Clark		•			•				?													
Pleurotoma harrisi Clark																						
Pleurotoma potomacensis C. & M.																						
Pleurotoma ducateli C. & M.																						
Pleurotoma childreni Lea.																						
Pleurotoma piscatavensis C. & M.																						
Pleurotoma tysoni C. & M.																						
Mangilia bellistriata Clark								•														
Cancellaria sp.																						
Cancellaria graciloides Ald. *var.*																						
Cancellaria potomacensis C. & M.																						
Olivula sp.																						
Volutilithes sp.								•														
Caricella pyruloides ? (Conrad)																						
Mitra marylandica ? Clark																						
Mitra pomonkensis C. & M.																						

TABLE SHOWING THE DISTRIBUTION OF THE EOCENE FAUNA.

SPECIES.	AQUIA FORMATION.																													
	POTOMAC RIVER.																	RAPPAHANNOCK RIVER.							MATTAPONI RIVER.		PAMUNKEY RIVER.	JAMES RIVER.		
	Fort Washington.	Tinkers Creek, near Piscataway.	1 mile N. E. of Piscataway.	Piscataway Creek.	Swan Creek, near Piscataway.	Pomonkey Neck.	Glymont.	1 mile S. E. of Mason Springs.	Mattawoman Creek.	Reedy Run.	Liverpool Point.	Wades Bay.	Clifton Beach.	Aquia Creek.	Potomac Creek.	Paspotansa Creek.	2 miles below Potomac Creek.	1 mile below Massaponax Creek.	3 miles below Massaponax Creek.	1¼ mile above Ware Creek.	Radcliffe's Wharf.	Above Hopyard Wharf.	2½ miles below Hopyard Wharf.	Near Brooke.	Mattaponi River, R. F. and P. R. R. Bridge.	Mattaponi River, first county bridge below R. R.	Pamunkey River, ½ mile S. E. of Wickham.	James River, Richmond.	James River, Deep Bottom.	James River, City Point.
nacensis C. & M.			•											•																
ylandicus C. & M.														•			•													
tenuis Heilprin																	•													
erstriatus Heilprin			•											•																
bleris Harris			•																											
subscalarina Heilprin											•				•		•													
? *potomacensis* C. & M.															•															
ylandica C. & M.	•																•													
	•						•						•	•																
p.													•	•																
rabeatus ? Conrad																														
ylandica C. & M.								•							•		•													
s engonatus (Heilprin)															•		•													
howalteri (Conrad)																•	•													
ta var. Conrad																														
.																														
argutus Clark						•									•		•													
uvenis (Whitfield)																	•													
identata (Aldrich)								•									•													
ithi Aldrich																														
rus trinodiferus Conrad															•		•													
rus trinodiferus ? *var.*								•																						
otomacensis C. & M.			•												•	•	•													
umerosa Conrad	•	•	•				•	•			•		•	•		•														
mortoni Conrad	•	•	•				•	•			•		•	•		•		•	•	•	•	•	•		•				•	•
otomacensis C. & M.																														
ruta (Conrad)																														
tonensis Clark													•																	
p.				•											•															
arylandica Conrad	•		•				•	•			•			•	•	•	•			•	•		•							
aperta (Solander)	•						•	•			•		•	•	•		•													
rylandica C. & M.																	•													
p.								•						•																
niana Clark														•	•															
nacensis C. & M.																	•													
lis Conrad																	•													
ata Lea																	•													
potomacensis C. & M.															•		•													
landica C. & M.								•								•														
trapaquara (Harris)															•		•													
icata (Lea)															•															
andula (Conrad)				•											•															
sp.																	•		•											
LLUSCA. Scaphopoda.																														
minutistriatum Gabb																														
ruptus Meyer & Aldich			•								•		•	•																
LLUSCA. Pelecypoda.																														
giniana Clark			•					•					•				•													
na sp.														•																
petrosa (Conrad)	•			•									•	•																

TABLE SHOWING THE DISTRIBUTION OF THE EOCENE FAUNA.

SPECIES.	NANJEMOY FORMATION.																						
	POTOMAC RIVER.									RAPPAHANNOCK RIVER.			MATTAPONI RIVER.								PAMUNKEY RIVER.		JA RI
	Potomac Creek.	Nanjemoy Creek.	½ mile below Chapel Point.	2½ miles above Popes Creek.	Woodstock. Zone 15.	2 miles above Popes Creek.	1½ mile above Popes Creek.	Popes Creek.	Woodstock. Zones 16 and 17.	Rappahannock River, Hopyard.	1¼ mile below Mount Creek.	¾ mile above Port Conway.	2 miles below Port Conway.	Mattaponi River, ½ mile below county bridge to Penola.	½ mile above Burke's Bridge.	3 to 4 miles below Burke's Bridge.	2½ miles below Reedy's Mill Bridge.	4¾ miles below Reedy's Mill Bridge.	2 miles below Marriccossick Creek.	3 miles below Marriccossick Creek.	Pamunkey River, Newcastle.	Pamunkey River, 1 mile east of Newcastle.	James River, Tar Bay.
REPTILIA.																							
Thecachampsa sp.																							
Thecachampsa contusor Cope																							
Thecachampsa marylandica Clark																							
Euclastes ? sp.																							
Trionyx virginiana Clark																							
PISCES.																							
Myliobatis copeanus Clark									•														
Aetobatis arcuatus Agassiz								•															
Synechodus clarkii Eastman																							
Odontaspis elegans (Agassiz)																							
Odontaspis macrota (Agassiz)									•														
Odontaspis cuspidata (Agassiz)								•	•														
Otodus obliquus Agassiz																							
Carcharodon auriculatus (Bln.)								•															
Galeocerdo latidens Agassiz									•														
Sphyrna prisca Agassiz																							
Xiphias ? radiata (Clark)																							
ARTHROPODA. Ostracoda.																							
Cytheridea perarcuata Ulrich									•														
MOLLUSCA. Cephalopoda.																							
Hercoglossa tuomeyi C. & M.								•															
MOLLUSCA. Gastropoda.																							
Tornatellaea bella Conrad					•				?														
Ringicula dalli Clark									•														
Cylichna venusta Clark		•			•				?														
Pleurotoma harrisi Clark																							
Pleurotoma potomacensis C. & M.																							
Pleurotoma ducateli C. & M.																							
Pleurotoma childreni Lea.																							
Pleurotoma piscatavensis C. & M.																							
Pleurotoma tysoni C. & M.																							
Mangilia bellistriata Clark																							
Cancellaria sp.								•															
Cancellaria graciloides Ald. *var.*																							
Cancellaria potomacensis C. & M.																							
Olivula sp.																							
Volutilithes sp.								•															
Caricella pyruloides ? (Conrad)																							
Mitra marylandica ? Clark																							
Mitra pomonkensis C. & M.																							

TABLE SHOWING THE DISTRIBUTION OF THE EOCENE FAUNA.

SPECIES.	AQUIA FORMATION.																													
	POTOMAC RIVER.																	RAPPAHANNOCK RIVER.							MATTAPONI RIVER.		PAMUNKEY RIVER.	JAMES RIVER.		
	Fort Washington.	Tinkers Creek, near Piscataway.	1 mile N. E. of Piscataway.	Piscataway Creek.	Swan Creek, near Piscataway.	Pomonkey Neck.	Glymont.	1 mile S. E. of Mason Springs.	Mattawoman Creek.	Reedy Run.	Liverpool Point.	Wades Bay.	Clifton Beach.	Aquia Creek.	Potomac Creek.	Paspotansa Creek.	2 miles below Potomac Creek.	1 mile below Massaponax Creek.	3 miles below Massaponax Creek.	1¼ mile above Ware Creek.	Radcliffe's Wharf.	Above Hopyard Wharf.	2½ miles below Hopyard Wharf.	Near Brooke.	Mattaponi River, R. F. and P. R. R. Bridge.	Mattaponi River, first county bridge below R. R.	Pamunkey River, ⅛ mile S. E. of Wickham.	James River, Richmond.	James River, Deep Bottom.	James River, City Point.
longata Conrad	●	●	●	●		●	●	●					●	●	●	●	●												●	
ubengonata Dall			●				●	●	●				●				●													
ldrichi Meyer											●		●	●					●	●										
miscus Conrad							●																							
mensis ? Aldrich																														
rginiana Clark	●	●				●		●					●	●			●													
lliamsi Clark															●															
pyria ? Conrad	●																													
btriangularis																														
enis (Conrad)																														
vata var. ovata (Rogers)																														
vata var. pyga Conrad	●						●	●	?	●	●		●	●	●	●	●		●	●	●		●	●	●			●		
bimpressa Conrad																														
lenticularis (Rogers)	●		●				●		●	●	●		●	●	●				●					●	●			●		
laevis Conrad			●					●						●	●		●													
hoppinensis																				●										
uiana Clark														●																
tertiformis Aldrich																														
rtoni Clark																														
lari Clark			●				●	●	●		●		●		●															
ittei Clark																														
.																				●										
lis planicosta var. regia Con.	●		●	●										●		●	●											●		
lis marylandica C. & M.																														
lis potapacoensis C. & M.																														
tes alaeformis (Conrad)	●		●				●		●		●	●	●			●	●	●	●	●	●	●	●						●	●
tes aquiana (Clark)							●		●	●	●			●	●															
tes sp.													●																	
nga bryani Clark						●																								
? sp.																			●											
ps marylandica Con.	●			●									●	●																
marylandicus C. & M.																														
alabamensis Ald.	●							●			●	●	●	●	●	●	●		●	●	●				●					
ps marylandica C. & M.													●																	
marylandica C. & M.													●							●										
ectavensis Aldrich			●																											
alli Clark															●															
hnsoni Clark															●	●														
p.															●															
lleformis Conrad																														
mpressirostra Say	●	●	●					●	●	●	●	●	●	●	●	●	●	●	●	●	●			●	●					●
mpressirostra var. alepidota Dall	●													●																
Gryphaeostrea) vomer (Morton)				●			●							●	●		●													
vesicularis Lamarck																														
rus (Rogers)																														
lliformis (Rogers)														●																
rus decisa (Con.) var.																														
gigantea Conrad	●		●				●	●			●		●	●	●		●			●	●	●			●			●		
ensis (Conrad)																														
ris idoneus (Conrad)			●																											

TABLE SHOWING THE DISTRIBUTION OF THE EOCENE FAUNA.

SPECIES.	NANJEMOY FORMATION.																								
	POTOMAC RIVER.									RAPPAHANNOCK RIVER.			MATTAPONI RIVER.								PAMUNKEY RIVER.		JAME RIVE		
	Potomac Creek.	Nanjemoy Creek.	½ mile below Chapel Point.	2½ miles above Popes Creek.	Woodstock. Zone 15.	2 miles above Popes Creek.	1½ mile above Popes Creek.	Popes Creek.	Woodstock. Zones 16 and 17.	Rappahannock River, Hopyard.	1½ mile below Mount Creek.	¾ mile above Port Conway.	2 miles below Port Conway.	Mattaponi River, ½ mile below county bridge to Penola.	½ mile above Burke's Bridge.	3 to 4 miles below Burke's Bridge.	2½ miles below Reedy's Mill Bridge.	4¾ miles below Reedy's Mill Bridge.	2 miles below Marriccossick Creek.	3 miles below Marriccossick Creek.	Pamunkey River, Newcastle.	Pamunkey River, 1 mile east of Newcastle.	James River, Tar Bay.	James River, Evergreen.	James River, Indian Field Point
Mitra potomacensis C. & M.								•	•																
Latirus marylandicus C. & M.																									
Fusus ? subtenuis Heilprin																									
Fusus ? interstriatus Heilprin									•																
Trophon sublevis Harris																									
Strepsidura subscalarina Heilprin								•	•																
Melongena ? potomacensis C. & M.																									
Tudicla marylandica C. & M.																									
Tudicla sp.																									
Tudicla ? sp.								•																	
Levifusus trabeatus ? Conrad								•	•																
Metula marylandica C. & M.																									
Chrysodomus engonatus (Heilprin)																									
***Tritonium showalteri* (Conrad)**																									
Pyrula penita var. Conrad								•																	
Pyrula ? sp.								•																	
Fulguroficus argutus Clark																									
Fusoficula juvenis (Whitfield)																									
Morio brevidentata (Aldrich)																									
Cypraea smithi Aldrich		•	•																						
Calyptraphorus trinodiferus Conrad	•																							•	
Calyptraphorus trinodiferus ? var.								•																	
Aporrhais potomacensis C. & M.																									
Turritella humerosa Conrad																									
Turritella mortoni Conrad																									
Turritella potomacensis C. & M.								•	•																
***Mesalia obruta* (Conrad)**								•	•			•													
Natica cliftonensis Clark									?																
Vermetus sp.																									
Lunatia marylandica Conrad					•				?																
Calyptraea aperta (Solander)			•					•	•																
Litiopa marylandica C. & M.																									
Solarium sp.																									
Scala virginiana Clark																									
Scala potomacensis C. & M.																									
Scala sessilis Conrad																									
Scala carinata Lea.																									
Turbonilla pottomacensis C. & M.																									
Tuba marylandica C. & M.								•																	
Odostomia trapaquara (Harris)																									
Niso umbilicata (Lea)																									
Gibbula glandula (Conrad)																									
Calliostoma sp.																									
MOLLUSCA. Scaphopoda.																									
Dentalium minutistriatum Gabb								•																	
Cadulus abruptus Meyer & Aldrich		•		•			•		•			•													
MOLLUSCA. Pelecypoda.																									
Teredo virginiana Clark			•	•				•																	
Gastrochaena sp.																									
Phenacomya petrosa (Conrad)																									

TABLE SHOWING THE DISTRIBUTION OF THE EOCENE FAUNA.

SPECIES.	AQUIA FORMATION.																													
	POTOMAC RIVER.																	RAPPAHANNOCK RIVER.							MATTAPONI RIVER.		PAMUNKEY RIVER.	JAMES RIVER.		
	Fort Washington.	Tinkers Creek, near Piscataway.	1 mile N. E. of Piscataway.	Piscataway Creek.	Swan Creek, near Piscataway.	Pomonkey Neck.	Glymont.	1 mile S. E. of Mason Springs.	Mattawoman Creek.	Reedy Run.	Liverpool Point.	Wades Bay.	Clifton Beach.	Aquia Creek.	Potomac Creek.	Paspotansa Creek.	2 miles below Potomac Creek.	1 mile below Massaponax Creek.	3 miles below Massaponax Creek.	1¼ mile above Ware Creek.	Radcliffe's Wharf.	Above Hopyard Wharf.	2½ miles below Hopyard Wharf.	Near Brooke.	Mattaponi River, R. F. and P. R. R. Bridge.	Mattaponi River, first county bridge below R. R.	Pamunkey River, ½ mile S. E. of Wickham.	James River, Richmond.	James River, Deep Bottom.	James River, City Point.
longata Conrad	•	•	•	•		•	•	•					•	•	•	•	•												•	
bengonata Dall			•				•	•	•				•				•													
ldrichi Meyer											•		•	•					•	•										
niscus Conrad							•																							
mensis ? Aldrich																														
rginiana Clark	•	•				•		•					•	•			•													
lliamsi Clark															•															
pyria ? Conrad	•																													
btriangularis																														
lenis (Conrad)																														
vata var. ovata (Rogers)																														
vata var. pyga Conrad	•						•	•	?	•	•		•	•	•	•	•		•	•	•		•	•	•			•		
ubimpressa Conrad																														
lenticularis (Rogers)	•		•				•		•	•	•		•	•	•				•					•	•			•		
a lenis Conrad			•					•						•	•	•	•													
hoppinensis																				•										
uiana Clark														•																
tartiformis Aldrich																														
rtoni Clark																														
leri Clark			•				•	•	•		•		•		•		•													
hitei Clark																														
.																				•										
lia planicosta var. regia Con.	•		•	•										•	•	•	•											•		
lia marylandica C. & M.																														
lia potapacoensis C. & M.																														
ites alaeformis (Conrad)	•		•				•	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•						•	•
ites aquiana (Clark)							•		•	•	•			•	•															
ites sp.													•																	
aga bryani Clark						•		•																						
? sp.																			•											
ya marylandica Con.	•			•									•	•																
marylandicus C. & M.																														
alabamensis Ald.	•						•	•			•	•	•	•	•	•	•		•	•	•				•					
pa marylandica C. & M.													•																	
arylandica C. & M.													•							•										
octavensis Aldrich			•																											
alli Clark															•															
hnsoni Clark															•	•	•													
p.															•															
laeformis Conrad																														
mpressirostra Say	•	•	•		•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•			•	•					•
mpressirostra var. alepidota Dall	•													•																
Gryphaeostrea) vomer (Morton)				•			•							•	•		•													
vesicularis Lamarck													•																	
va (Rogers)																														
telliformis (Rogers)														•																
rea decisa (Con.) *var.*																														
gigantea Conrad	•		•				•	•			•		•	•	•	•	•			•	•	•			•			•		
mula (Conrad)																														
is idoneus (Conrad)			•												•															

TABLE SHOWING THE DISTRIBUTION OF THE EOCENE FAUNA.

SPECIES.	NANJEMOY FORMATION.																							
	POTOMAC RIVER.									RAPPAHANNOCK RIVER.			MATTAPONI RIVER.								PAMUNKEY RIVER.		JAM RIVI	
	Potomac Creek.	Nanjemoy Creek.	½ mile below Chapel Point.	2½ miles above Popes Creek.	Woodstock. Zone 15.	2 miles above Popes Creek.	½ mile above Popes Creek.	Popes Creek.	Woodstock. Zones 16 and 17.	Rappahannock River, Hopyard.	1½ mile below Mount Creek.	¾ mile above Port Conway.	2 miles below Port Conway.	Mattaponi River, ½ mile below county bridge to Penola.	½ mile above Burke's Bridge.	3 to 4 miles below Burke's Bridge.	2½ miles below Reedy's Mill Bridge.	4¾ miles below Reedy's Mill Bridge.	2 miles below Marriccossick Creek.	3 miles below Marriccossick Creek.	Pamunkey River, Newcastle.	Pamunkey River, 1 mile east of Newcastle.	James River, Tar Bay.	James River, Evergreen.
Panopea elongata Conrad																								
Corbula subengonata Dall								•	•															
Corbula aldrichi Meyer		•	•	•			•	•	•		•	•	•			•			•		•			
Corbula oniscus Conrad		•		•				•	•															
Solen lisbonensis ? Aldrich			•		•				?															
Tellina virginiana Clark				•				•	•															
Tellina williamsi Clark				•				•	•															
Tellina papyria ? Conrad																								
Tellina subtriangularis												•	•											
Meretrix lenis (Conrad)									•															
Meretrix ovata var. ovata (Rogers)		•	•	•		•		•				•	•						•	•				
Meretrix ovata var. pyga Conrad																								
Meretrix subimpressa Conrad								•	•		•										•			
Dosiniopsis lenticularis (Rogers)																								
Protocardia lenis Conrad								•	•															
Diplodanta hoppinensis																								•
Lucina aquiana Clark																								
Lucina astartiformis Aldrich																								
Lucina dartoni Clark				•				•	•	•														
Lucina uhleri Clark								•	•															
Lucina whitei Clark			•						•															
Lucina sp.								•																
Venericardia planicosta var. regia Con.																								
Venericardia marylandica C. & M.				•	?	•		•	?															
Venericardia potapacoensis C. & M.	•	•	•	•		•		•	•		•	•	•					•	•	•	•	•		
Crassatellites alaeformis (Conrad)																								
Crassatellites aquiana (Clark)																								
Crassatellites sp.																								
Coralliophaga bryani Clark																								
Periploma ? sp.					•				?															
Pholadamya marylandica Con.																								
Modiolus marylandicus C. & M.									•															
Modiolus alabamensis Ald.				•				•	•															
Lithophaga marylandica C. & M.																								
Anomia marylandica C. & M.								•	•															
Pecten choctavensis Aldrich				•			•	•																•
Pecten dalli Clark									•															
Pecten johnsoni Clark									•															
Pecten sp.																								
Ostrea sellaeformis Conrad				•			•	•	•													•	•	
Ostrea compressirostra Say																								
Ostrea compressirostra var. alepidota Dall																								
Ostrea (Gryphaeostrea) vomer (Morton)			•																					
Gryphaea vesicularis Lamarck																								
Leda parva (Rogers)				•		•		•	•												•			
Leda cultelliformis (Rogers)				•		•		•	•				•											
Trigonoarca decisa (Con.) *var.*									•															
Cullaea gigantea Conrad								•	•															
Pteria limula (Conrad)								•																
Glycymeris idoneus (Conrad)								•	•												•	•		

TABLE SHOWING THE DISTRIBUTION OF THE EOCENE FAUNA.

SPECIES.	AQUIA FORMATION.																													
	POTOMAC RIVER.																	RAPPAHANNOCK RIVER.							MATTAPONI RIVER.		PAMUNKEY RIVER.	JAMES RIVER.		
	Fort Washington.	Tinkers Creek, near Piscataway.	1 mile N. E. of Piscataway.	Piscataway Creek.	Swan Creek, near Piscataway.	Pomonkey Neck.	Glymont.	1 mile S. E. of Mason Springs.	Mattawoman Creek.	Reedy Run.	Liverpool Point.	Wades Bay.	Clifton Beach.	Aquia Creek.	Potomac Creek.	Paspotansa Creek.	2 miles below Potomac Creek.	1 mile below Massaponax Creek.	3 miles below Massaponax Creek.	1¼ mile above Ware Creek.	Radcliffe's Wharf.	Above Hopyard Wharf.	2½ miles below Hopyard Wharf.	Near Brooke.	Mattaponi River, R. F. and P. R. R. Bridge.	Mattaponi River, first county bridge below R. R.	Pamunkey River, ½ mile S. E. of Wickham.	James River, Richmond.	James River, Deep Bottom.	James River, City Point.
sensis C. & M.											•		•	•	•		•													
i C. & M.																											•			
s (Conrad)																														
cera (Conrad)																														
s var.																														
acensis C. & M.																														
omacensis C. & M.																														
LUSCOIDEA. Bryozoa.																														
micropora Goldf																														
reversa Ulrich																	•													
COELENTERATA.																														
sp.														•																
acuticostata Vaughan															•															
hus clarkeanus Vaughan			•											•	•															
is marylandicus Vaughan			•																											
elaborata (Conrad)								•						•	•															
PROTOZOA.																														
gramen d'Orbigny			•																											
affinis (d'Orbigny)																														
bacillum Defrance								•									•													
rotatula (Lamarck)								•																						
radiata (Bornemann)																														
gibba d'Orbigny			•																											
ina austriaca (d'Orbigny)																														
ina communis d'Orbigny																														
ina compressa d'Orbigny																														
ina elegantissima P. & J.																														
ina gibba d'Orbigny																														
ina lactea (W. & J.)																														
ina praelonga Terq.																														
bulloides d'Orbigny																														
berthelotii (d'Orbigny)																														
grosserugosa (Gumbel)			•																											
na lobatula (W. & J.)																														
exigua var. obtusa Bur.			•																											
schreibersii (d'Orbigny)																														
affinis Reuss																														
na lessonii d'Orbigny																														
marylandicus Hollick																														
marylandicus var. rugosus H.																														

TABLE SHOWING THE DISTRIBUTION OF THE EOCENE FAUNA.

SPECIES.	Nanjemoy Formation.																					
	POTOMAC RIVER.									RAPPAHANNOCK RIVER.			MATTAPONI RIVER.								PAMUNKEY RIVER.	
	Potomac Creek.	Nanjemoy Creek.	½ mile below Chapel Point.	2½ miles above Popes Creek.	Woodstock. Zone 15.	2 miles above Popes Creek.	1½ mile above Popes Creek.	Popes Creek.	Woodstock. Zones 16 and 17.	Rappahannock River, Hopyard.	1½ mile below Mount Creek.	¾ mile above Port Conway.	2 miles below Port Conway.	Mattaponi River, ½ mile below county bridge to Penola.	½ mile above Burke's Bridge.	3 to 4 miles below Burke's Bridge.	2½ miles below Reedy's Mill Bridge.	4¾ miles below Reedy's Mill Bridge.	2 miles below Marriccossick Creek.	3 miles below Marriccossick Creek.	Pamunkey River, Newcastle.	Pamunkey River, 1 mile east of Newcastle.
Leda cliftonensis C. & M.																						
Leda tysoni C. & M.				●				●	●													
Leda parilis (Conrad)																					●	
Leda improcera (Conrad)		●		●				●	●										●			
Leda parilis var.									●													
Leda potomacensis C. & M.			●					●														
Nucula potomacensis C. & M.		●		●				●	●			●							●		●	
Molluscoidea. Bryozoa.																						
Ceriopora micropora Goldf.				●																		
Lunulites reversa Ulrich																						
Coelenterata.																						
Flabellum sp.									●													
Turbinolia acuticostata Vaughan								●														
Trochocyathus clarkeanus Vaughan																						
Paracyathus marylandicus Vaughan																						
Eupsammia elaborata (Conrad)																						
Protozoa.																						
Textularia gramen d'Orbigny																						
Nodosaria affinis (d'Orbigny)									●													
Nodosaria bacillum Defrance									●													
Cristellaria rotatula (Lamarck)																						
Cristellaria radiata (Bornemann)									●													
Cristellaria gibba d'Orbigny									●													
Polymorphina austriaca (d'Orbigny)									●													
Polymorphina communis d'Orbigny									●													
Polymorphina compressa d'Orbigny									●													
Polymorphina elegantissima P. & J.									●													
Polymorphina gibba d'Orbigny																						
Polymorphina lactea (W. & J.)																						
Polymorphina praelonga Terq.									●													
Globigerina bulloides d'Orbigny									●													
Discorbina bertheloti (d'Orbigny)									●													
Anomalina grosserugosa (Gumbel)																						
Truncatulina lobatula (W. & J.)									●													
Pulvinulina exigua var. obtusa Bur.																						
Pulvinulina schreibersii (d'Orbigny)									●													
Nonionina affinis Reuss									●													
Amphistegina lessonii d'Orbigny									●													
Carpolithus marylandicus Hollick								●														
Carpolithus marylandicus var. rugosus H.								●														

MIOCENE.

THE CHESAPEAKE GROUP.

The Miocene deposits of Virginia form part of a broad belt of formations of that age which extend from New Jersey southward to the South Atlantic States. The strata attain considerable thickness and constitute the most important element in the Coastal Plain series with the exception of the Cretaceous beds which are usually thicker than the Miocene although the latter, because of a gentler dip, outcrop over a much wider belt in Virginia and Maryland. In North Carolina, on the other hand, through the removal of much of the Miocene by erosion the underlying Cretaceous beds have a more extensive outcrop.

The materials composing the Miocene formations are largely fine-grained, light-colored sands which are mostly unconsolidated except where locally cemented by carbonate of lime derived from the fossil shells which form such an important feature of the deposits. Diatomaceous earth is also characteristic of the Miocene deposits and occurs in thick beds in its lower portions. A dark blue, often greenish, clay is likewise common in some of the deposits.

It has been found possible, on the basis of the fossils and the lithological characteristics, to divide the Miocene of the Chesapeake Bay region into four formations, known as the Calvert, the Choptank, the St. Mary's, and the Yorktown. These were first grouped together under one formation which was named the Chesapeake formation because of its great development in the Chesapeake Bay drainage basin. The name is now retained as a group name, and very properly, because the four Miocene formations exposed in the region of the Chesapeake Bay form a group of deposits formed under very similar conditions and possessing many striking similarities which distinguish them from the underlying Eocene and the overlying Pliocene (?) and Pleistocene strata. The surface of the Chesapeake group is, for the most part, covered on the divides by deposits of Pleistocene age, but along the estuaries and tributary streams there are many excellent exposures.

Except for the comparatively superficial deposits of the Pleistocene, the Miocene strata are much more widely distributed in the Coastal Plain of Virginia than the strata of any other age. They make their first appearance in the high divides of Stafford County a few miles northeast of Fredericksburg where they overlie the Nanjemoy deposits. From this point they extend in an almost continuous sheet to the south and southeast and are exposed along almost every stream that has cut through the superficial Pleistocene capping. The most numerous exposures are along the channels of the Potomac, Rappahannock, York, and James rivers. No outcrops of Miocene beds appear on the Bay shore as in Maryland since the bluffs are low and as far as known consist entirely of Quaternary deposits.

The Calvert Formation.

Name.—The basal beds of the Miocene constitute the Calvert formation which receives its name from Calvert County, Maryland, where in the famous Calvert Cliffs are to be seen perhaps the best exposures of the strata of this age anywhere in the Atlantic Coastal Plain. The name was first applied to these deposits by G. B. Shattuck[a] in 1902.

Stratigraphic relations.—The deposits of the Calvert rest unconformably upon the Nanjemoy formation throughout most of the Coastal Plain. In the James River basin, however, this formation transgresses the Nanjemoy and rests on the exposed margins of the Aquia formation while farther south it also transgresses the Aquia and about Petersburg is in contact with the Patuxent beds. Still farther to the south the Miocene at its western margin rests upon the crystalline rocks of the Piedmont Plateau.

The Calvert is unconformably overlain by the Choptank formation in Maryland but whenever exposures of the contact have been found in Virginia the St. Mary's formation succeeds the Calvert unconformably. It is possible, as stated later, that the Choptank formation may overlie the Calvert for a short distance on the south side of the Potomac as on the north side in Maryland but it seems more probable that this formation has already thinned out and disappeared before the south side of the Potomac is reached. It is impossible to definitely determine this point in the absence of an exposed contact in this area due to the cover of Pleistocene deposits.

Lithologic character.—The Calvert formation consists largely of sands, clays, marls, and diatomaceous earth. Fine-grained, light-colored sands predominate. The clays, which usually contain considerable sand, are dark blue to black in color, weathering to a gray or sometimes to a dull white on exposure. They grade into sands through an increase in the arenaceous matter, or into diatomaceous earth due to an increasing number of diatom tests. The blue clay almost invariably contains numerous casts of small shells although at times the original shell substance still remains. Gypsum crystals, sometimes single, at other times arranged in rosettes, are frequently found. The clay also carries at times considerable glauconite, so much that locally it closely resembles the Eocene greensand. Such an occurrence can be seen at the base of the Wilmont bluffs below Port Conway on the Rappahannock River.

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[a] Science, Vol. xv, 1902, p. 906.

Deposits of diatomaceous earth constitute the most striking feature of the Calvert. These consist of countless millions of microscopic siliceous tests of diatoms. They are so small that Ehrenberg estimated that one cubic inch of Bohemian diatomaceous earth contained about 40,000,000 tests. When the diatomaceous earth is pure it is white in color and very light in weight. It, however, contains very frequently considerable argillaceous material and then is apt to be blue in a fresh exposure but whitens by contact with the atmosphere. It is often slightly discolored by the presence of small quantities of hydrous oxide of iron.

The diatomaceous earth beds of the Calvert extend across the states of New Jersey, Delaware, Maryland, and Virginia. They have been penetrated in some of the deep wells at Atlantic City where they have a thickness of about 300 feet. They are well exposed in Maryland at Herring Bay and Pope's Creek. At Wilmont bluffs on the Rappahannock River they have a thickness of about 50 feet in bold, almost vertical cliffs which present an appearance almost as white as chalk when viewed from a distance. Other good exposures are at Carter's Wharf on the Rappahannock River and along Shockoe Creek in the eastern part of Richmond, where a thickness of about 20 feet is shown. The diatomaceous earth also passes frequently under the names of infusorial earth, tripoli, Richmond earth, and Bermuda earth.

Strike, dip and thickness.—The strike of the Calvert formation is parallel to the line of outcrop, namely, north and south, while the beds dip to the east at the rate of about 10 feet to the mile. The thickness of the beds is about 200 feet.

Areal distribution.—The formation makes its appearance in southern New Jersey where it occurs at Shiloh and Jerico, crosses Delaware and Maryland as a gradually widening belt, 10 to 30 miles in width, and continues as far south as Prince George County, Virginia, with a width frequently greater than in Maryland. It is excellently exposed in hundreds of places along the Potomac, Rappahannock, Mattaponi, Pamunkey, James, and Nottoway rivers and their tributaries in the counties of King George, Westmoreland, Essex, Caroline, Hanover, Henrico, King and Queen, King William, New Kent, Charles City, and Prince George. It also occupies small areas in a number of other counties both to the east and to the west of the ones named. In the northern part of this area, particularly in Stafford

County, the Calvert is found some miles to the east of the "fall line" but to the south it extends much farther west and is found lying upon the Piedmont crystallines. Throughout much of the Virginia Coastal Plain outliers of the Lafayette alone extend farther westward.

The Calvert formation occupies the higher-lying lands along the western portions of its area of outcrop with the Eocene and Potomac formations in the lower parts of the valleys and gradually dips to lower and lower levels as it passes to the east, until it finally sinks beneath tide level. The line along which it disappears is in the vicinity of Nomini Bay on the Potomac River and at about the same longitude along the Rappahannock River. It disappears at West Point where the Mattaponi and Pamunkey rivers unite to form York River. From that point the eastern limit takes a southwesterly course to a point a short distance south of Petersburg where it disappears entirely. The formation has not been recognized in Sussex, Greenesville, and Southampton counties. In the first two the St. Mary's is in contact with the crystalline rocks of the Piedmont Plateau.

Paleontologic character.—Fossils are especially abundant in the Calvert strata of Virginia, and represent a wide range of species. As shown in the faunal tables on a later page, fossils belonging to most of the larger groups of animals occur in the Calvert, and certain forms are to be found in almost every place where the formation outcrops. Besides the faunal remains, the Calvert has yielded an abundance of plant fossils. Most of these are microscopic, and belong to the group of the diatoms, but Berry, in 1909, described 14 species of higher plants from the diatomaceous earth of Richmond. About 200 species of diatoms have been described from the diatomaceous earth of Richmond and Petersburg, and careful examination would no doubt reveal the presence of many more.

DETAILED SECTIONS.

The Calvert formation is exposed in hundreds of places throughout its area of outcrop and in almost every case is easily recognized. Most of the sections are along the tributary streams where only a few feet of materials are exposed, while the best are those along the larger streams. The sections given below are typical of the formation and may be duplicated in scores of places throughout the State.

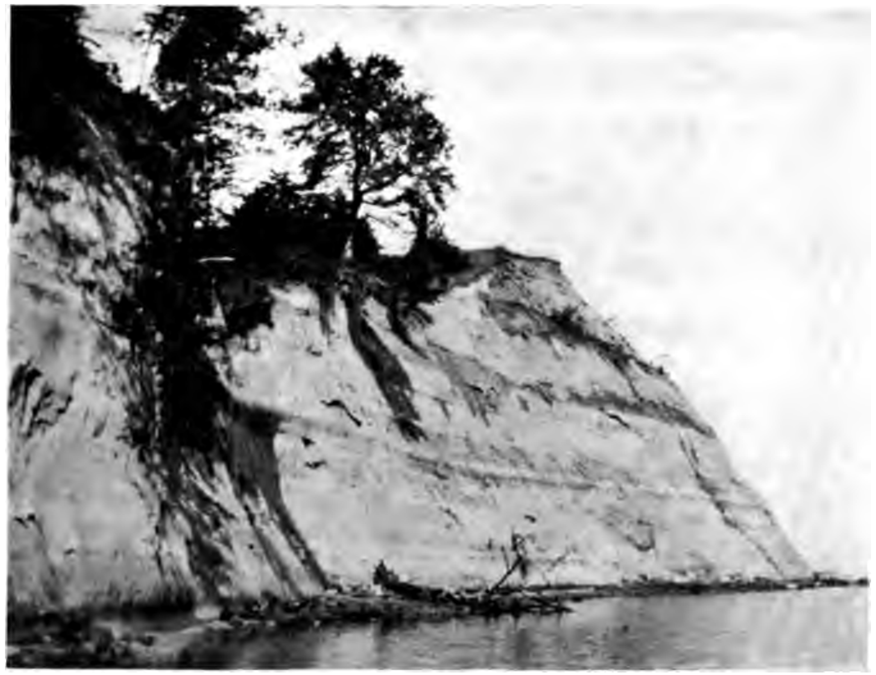

Fig. 1.—Nomini Cliffs, Potomac River. Showing Calvert formation.

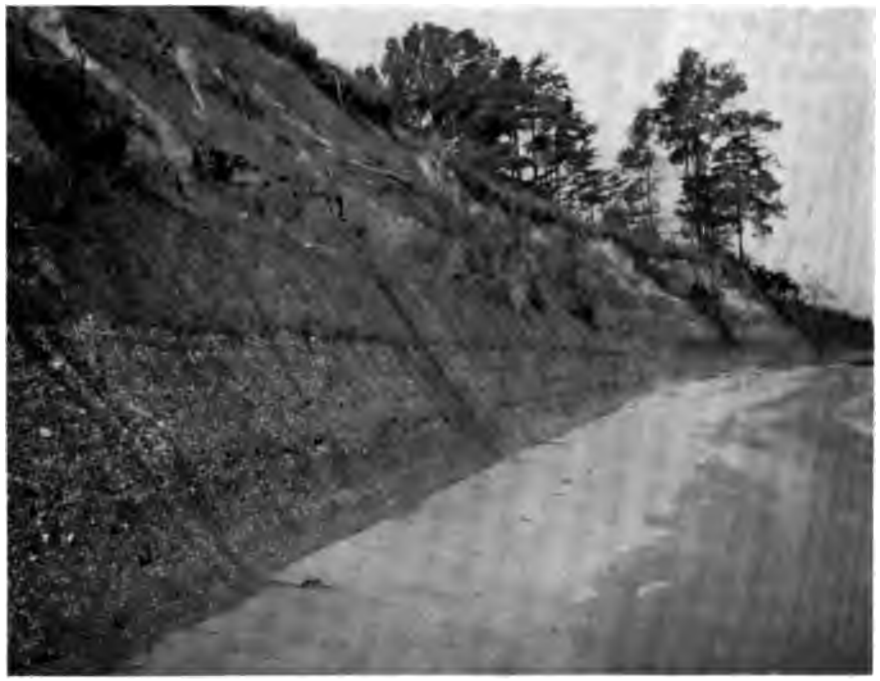

Fig. 2.—Section 1½ miles below Bowlers Wharf, Rappahannock River. Showing shell marl of St. Mary's formation.

CALVERT AND ST. MARY'S FORMATIONS.

SECTIONS IN THE POTOMAC RIVER VALLEY.

Along the Potomac River estuary the Calvert formation is finely exhibited in the Nomini Cliffs of Westmoreland County. These rise to a height of 200 feet and are so nearly vertical that it is impossible to scale them in most places. They are the boldest cliffs of the northern Atlantic Coastal Plain and form a striking contrast to the general topography of the region. They consist of Calvert and Pleistocene (Sunderland) materials exclusively. The following five sections give a fair idea of the cliffs.

I. *Section on the Potomac River, three-quarters of a mile southeast of the mouth of Pope Creek.*

			Feet
Miocene.	Calvert	White diatomaceous earth	15

II. *Section of the Nomini Cliffs of the Potomac River, three miles below mouth of Pope Creek.*

			Feet
Pleistocene.	Sunderland	Reddish clay loam	12
		Band of small gravel with reddish clay loam matrix	2
		Reddish clay	4
		Coarse buff sand	4
		Red ferruginous sandstone	3
		Very coarse yellow argillaceous sand not well exposed in lower portion	20
Miocene.	Calvert	Greenish-drab tough plastic clay	21
		Greenish-gray slightly indurated argillaceous sand, rusty where weathered along surface and making a prominent line along bluff. Contains sharks teeth and mammalian bones	1
		Dark greenish-gray very sandy fine-grained clay with a few diatoms	12
		Light greenish-drab sandy clay	7
		Greenish-gray slightly indurated argillaceous sand with shell impressions. Contains shells of *Pecten*, *Melina*, *Ecphora*, etc.	1
		Dark greenish-gray argillaceous sand grading into sandy clay	25
		Greenish-drab more or less arenaceous compact clay, containing diatoms; material light in weight when dry	18
		Total	130

TABLE SHOWING THE DISTRIBUTION OF THE EOCENE FAUNA.

SPECIES.	NANJEMOY FORMATION.																							
	POTOMAC RIVER.									RAPPA-HANNOCK RIVER.				MATTAPONI RIVER.							PAMUN-KEY RIVER.		JAMI RIVE	
	Potomac Creek.	Nanjemoy Creek.	½ mile below Chapel Point.	2½ miles above Popes Creek.	Woodstock. Zone 15.	2 miles above Popes Creek.	¼ mile above Popes Creek.	Popes Creek.	Woodstock. Zones 16 and 17.	Rappahannock River, Hopyard.	1½ mile below Mount Creek.	¾ mile above Port Conway.	2 miles below Port Conway.	Mattaponi River, ½ mile below county bridge to Penola.	½ mile above Burke's Bridge.	3 to 4 miles below Burke's Bridge.	2½ miles below Reedy's Mill Bridge.	4¾ miles below Reedy's Mill Bridge.	2 miles below Marriccossick Creek.	3 miles below Marriccossick Creek.	Pamunkey River, Newcastle.	Pamunkey River, 1 mile east of Newcastle.	James River, Tar Bay.	James River, Evergreen.
Panopea elongata Conrad																								
Corbula subengonata Dall								●	●															
Corbula aldrichi Meyer		●	●	●			●	●	●		●	●	●			●			●		●			
Corbula oniscus Conrad		●		●				●	●															
Solen lisbonensis ? Aldrich			●		●				?															
Tellina virginiana Clark				●				●	●															
Tellina williamsi Clark				●				●	●															
Tellina papyria ? Conrad																								
Tellina subtriangularis												●	●											
Meretrix lenis (Conrad)									●															
Meretrix ovata var. ovata (Rogers)		●	●	●		●		●				●	●						●	●				
Meretrix ovata var. pyga Conrad																								
Meretrix subimpressa Conrad								●	●		●										●			
Dosiniopsis lenticularis (Rogers)																								
Protocardia lenis Conrad								●	●															
Diplodanta hoppinensis																								●
Lucina aquiana Clark																								
Lucina astartiformis Aldrich																								
Lucina dartoni Clark				●				●	●	●														
Lucina uhleri Clark								●	●															
Lucina whitei Clark			●						●															
Lucina sp.								●																
Venericardia planicosta var. regia Con.																								
Venericardia marylandica C. & M.				●	?	●		●	?															
Venericardia potapacoensis C. & M.	●	●	●	●		●		●	●		●	●	●					●	●	●	●	●		
Crassatellites alaeformis (Conrad)																								
Crassatellites aquiana (Clark)																								
Crassatellites sp.																								
Coralliophaga bryani Clark																								
Periploma ? sp.					●				?															
Pholadamya marylandica Con.																								
Modiolus marylandicus C. & M.									●															
Modiolus alabamensis Ald.				●				●	●															
Lithophaga marylandica C. & M.																								
Anomia marylandica C. & M.								●	●															
Pecten choctavensis Aldrich				●			●	●																●
Pecten dalli Clark									●															
Pecten johnsoni Clark									●															
Pecten sp.																								
Ostrea sellaeformis Conrad				●			●	●	●													●	●	●
Ostrea compressirostra Say																								
Ostrea compressirostra var. alepidota Dall																								
Ostrea (Gryphaeostrea) vomer (Morton)			●																					
Gryphaea vesicularis Lamarck																								
Leda parva **(Rogers)**				●		●		●	●												●			
Leda cultelliformis **(Rogers)**				●		●		●	●				●											
Trigonoarca decisa **(Con.)** ***var***									●															
Cullaea gigantea **Conrad**								●	●															
Pteria limula **(Conrad)**								●																
Glycymeris idoneus **(Conrad)**								●	●												●	●		●

V. *Section of the Nomini Cliffs of the Potomac River, seven miles below mouth of Pope Creek.*

			Feet
Pleistocene		Reddish-yellow and gray sands, coarse sands, and gravel; indurated corrugated iron stone near base	20
Miocene.	Calvert	Greenish-gray more or less sandy clay	45
		Greenish-gray argillaceous sand slightly indurated. Contains mammalian bones	1
		Greenish-gray argillaceous sand	22
		Fossil band in greenish-gray clay	2
		Greenish-gray sandy clay	11
		Fossil band of greenish-gray argillaceous sand. Fossils especially numerous near base; *Melina* abundant	4
		Greenish-gray sandy clay containing a band of fossils near base; contains diatoms	20
		Total	125

Throughout the entire length of the Nomini Cliffs the beds seem to be almost horizontal. No single bed has been traced throughout the entire cliff section but layers have been traced for a mile or more in different places. The materials in general in sections II and V are about the same. There are certain undulations in the beds but no noticeable dip. In both cases the upper half of the Miocene is almost without fossils. The lower half has several prominent fossil bands at the centre. These continue toward the east but become less prominent in that direction. Diatoms are abundant in the lower 25 or 30 feet throughout the entire length of the cliffs but are less noticeable in the eastern portion. The fossil layer near the base of section IV is perhaps the same as the fossil band 20 to 24 feet above base in section V. Between section V and the extreme east end of the cliffs the beds again descend a few feet.

The fossils for the most part, except a few oysters, barnacles, and many pectens are soft and fragile. Some of the fossil layers in the Nomini Cliffs outcrop for a distance of a mile or more but none extends the entire length of the cliffs. There are very few fossils, if any, in section III. A few were noted in section II. The best place for collecting is between section IV and section V. It is probable that nearly all the beds exposed in the Nomini Cliffs, if perfectly fresh, would be dark green in color. In most places, however, more or less weathering has taken place so that they appear greenish-gray, light green, or even almost white.

TABLE SHOWING THE DISTRIBUTION OF THE EOCENE FAUNA.

	NANJEMOY FORMATION.																								
	POTOMAC RIVER.									RAPPAHANNOCK RIVER.			MATTAPONI RIVER.								PAMUNKEY RIVER.		JAME RIVE		
SPECIES.	Potomac Creek.	Nanjemoy Creek.	½ mile below Chapel Point.	2½ miles above Popes Creek.	Woodstock. Zone 15.	2 miles above Popes Creek.	1½ mile above Popes Creek.	Popes Creek.	Woodstock. Zones 16 and 17.	Rappahannock River, Hopyard.	1½ mile below Mount Creek.	¾ mile above Port Conway.	2 miles below Port Conway.	Mattaponi River, ½ mile below county bridge to Penola.	½ mile above Burke's Bridge.	3 to 4 miles below Burke's Bridge.	2¼ miles below Reedy's Mill Bridge.	4¾ miles below Reedy's Mill Bridge.	2 miles below Marriccossick Creek.	3 miles below Marriccossick Creek.	Pamunkey River, Newcastle.	Pamunkey River, 1 mile east of Newcastle.	James River, Tar Bay.	James River, Evergreen.	
Leda cliftonensis C. & M.																									
Leda tysoni C. & M.				•				•	•																
Leda parilis (Conrad)																					•				
Leda improcera (Conrad)		•		•				•	•										•						
Leda parilis var.									•																
Leda potomacensis C. & M.			•					•																	
Nucula potomacensis C. & M.		•		•				•	•			•							•		•				
MOLLUSCOIDEA. Bryozoa.																									
Ceriopora micropora Goldf.				•																					
Lunulites reversa Ulrich																									
COELENTERATA.																									
Flabellum sp.									•																
Turbinolia acuticostata Vaughan								•																	
Trochocyathus clarkeanus Vaughan																									
Paracyathus marylandicus Vaughan																								•	
Eupsammia elaborata (Conrad)																									
PROTOZOA.																									
Textularia gramen d'Orbigny																									
Nodosaria affinis (d'Orbigny)									•																
Nodosaria bacillum Defrance									•																
Cristellaria rotatula (Lamarck)																									
Cristellaria radiata (Bornemann)									•																
Cristellaria gibba d'Orbigny									•																
Polymorphina austriaca (d'Orbigny)									•																
Polymorphina communis d'Orbigny									•																
Polymorphina compressa d'Orbigny									•																
Polymorphina elegantissima P. & J.									•																
Polymorphina gibba d'Orbigny																									
Polymorphina lactea (W. & J.)																									
Polymorphina praelonga Terq.									•																
Globigerina bulloides d'Orbigny									•																
Discorbina bertheloti (d'Orbigny)									•																
Anomalina grosserugosa (Gumbel)																									
Truncatulina lobatula (W. & J.)									•																
Pulvinulina exigua var. obtusa Bur.																									
Pulvinulina schreibersii (d'Orbigny)									•																
Nonionina affinis Reuss									•																
Amphistegina lessonii d'Orbigny									•																
Carpolithus marylandicus Hollick								•																	
Carpolithus marylandicus var. rugosus H.								•																	

MIOCENE.

THE CHESAPEAKE GROUP.

The Miocene deposits of Virginia form part of a broad belt of formations of that age which extend from New Jersey southward to the South Atlantic States. The strata attain considerable thickness and constitute the most important element in the Coastal Plain series with the exception of the Cretaceous beds which are usually thicker than the Miocene although the latter, because of a gentler dip, outcrop over a much wider belt in Virginia and Maryland. In North Carolina, on the other hand, through the removal of much of the Miocene by erosion the underlying Cretaceous beds have a more extensive outcrop.

The materials composing the Miocene formations are largely fine-grained, light-colored sands which are mostly unconsolidated except where locally cemented by carbonate of lime derived from the fossil shells which form such an important feature of the deposits. Diatomaceous earth is also characteristic of the Miocene deposits and occurs in thick beds in its lower portions. A dark blue, often greenish, clay is likewise common in some of the deposits.

It has been found possible, on the basis of the fossils and the lithological characteristics, to divide the Miocene of the Chesapeake Bay region into four formations, known as the Calvert, the Choptank, the St. Mary's, and the Yorktown. These were first grouped together under one formation which was named the Chesapeake formation because of its great development in the Chesapeake Bay drainage basin. The name is now retained as a group name, and very properly, because the four Miocene formations exposed in the region of the Chesapeake Bay form a group of deposits formed under very similar conditions and possessing many striking similarities which distinguish them from the underlying Eocene and the overlying Pliocene (?) and Pleistocene strata. The surface of the Chesapeake group is, for the most part, covered on the divides by deposits of Pleistocene age, but along the estuaries and tributary streams there are many excellent exposures.

Except for the comparatively superficial deposits of the Pleistocene, the Miocene strata are much more widely distributed in the Coastal Plain of Virginia than the strata of any other age. They make their first appearance in the high divides of Stafford County a few miles northeast of Fredericksburg where they overlie the Nanjemoy deposits. From this point they extend in an almost continuous sheet to the south and southeast and

IV. *Section left bank of Rappahannock River, one-half mile above Carter's Wharf.*

			Feet
Pleistocene		Yellow and red coarse sand and gravel. Pebbles not exceeding a few inches in size. Numerous large boulders	10
Miocene.	Calvert	Pink and white clay	4
		Sand colored, various shades of red, pink, yellow, and gray	25
		Argillaceous sand, dark greenish-gray, where unweathered, light greenish-gray where weathered	32
		Ferruginous fossiliferous sand layer with *Pecten Venus, Dosinia, Turritella*, etc....	6 in.
		Dark green arenaceous clay	10
		Dark green argillaceous sand	9
		Ferruginous fossiliferous sand layer.......	6
		Dark green clay	5
		Dark green argillaceous sand	22
		Diatomaceous clay, white when dry........	18
		Total............................	141½

The above section resembles very closely the Nomini Cliffs and seems to represent the same horizon. The fossil layers mentioned contain only very decayed fossils. This is principally because the face of the bluff is very much weathered. It is probable that by digging into the fresh material good specimens could be obtained. The purest diatomaceous earth is contained in the lower 18 feet but it is probable that diatoms occur in the layers higher up. Slight differences in the sand and clay content cause the bluff to have a banded appearance. A few large mammalian vertebrae were observed about half way up the bluff. The exposure is a very striking one and furnishes an excellent section of the Rappahannock River Calvert materials.

A series of bluffs not so high or well exposed extends from the preceding section down stream for about 3 miles. The diatomaceous portion may be traced the entire distance with scarcely any variation in level showing that the Miocene beds are very nearly horizontal.

V. *Section right bank of Rappahannock River at Tappahannock.*

			Feet
Pleistocene		Loam grading down into sand with an intermixture of gravel........................	10-15
		Unconformity	
Miocene.	Calvert	Dark greenish-gray to olive green argillaceous clay, lighter in color where weathered......	5-10
		Total..............................	25

VI. *Section right bank of Rappahannock River, one-half mile below Bowler's Wharf and opposite Sharp's Wharf.*

			Feet
Pleistocene		Sand and gravel	20
Miocene.	Calvert	Dark greenish-gray sandy clay full of fossils most of which are well preserved	12
		Total	32

The strata with similar characteristics are exposed for almost a mile along the shore.

VII. *Section right bank of Rappahannock River one-half to one mile below preceding section.*

			Feet
Pleistocene		Yellow sand and sandy clay	14
Miocene.	Calvert	Dark green argillaceous sand full of fossils principally *Arca staminea*, *Venus*, *Fulgur coronatum*, *Turritella plebeia*, *Ostrea*, *Dentalium attenuatum*, numerous small pelecypods, etc.	4
		Greenish-gray, compact clay layer with thin sand laminae	13
		Dark green argillaceous sand or sandy clay with fossils; *Arca staminea*, *Venus*, numerous small pelecypods, etc.	2
		Total	33

The beds rise slightly toward the east and the lower fossil layer was observed to a height of 6 feet about one-half mile below where the section was taken.

SECTIONS ALONG THE MATTAPONI RIVER AND ITS TRIBUTARIES.

The Calvert formation outcrops in many places in the Mattaponi River valley and is remarkably uniform in its lithologic characteristics in the various exposures. Calvert strata are present along the entire course of this stream from near Bowling Green where it enters the Coastal Plain to its junction with the Pamunkey River at West Point. The formation outcrops in the tributary streams in the vicinity of Bowling Green but dips gently to the southeast and for many miles is exposed as a thin band in the low river bluffs lying between the Nanjemoy formation beneath and the Pleistocene above. A few miles above Walkerton the Nanjemoy formation disappears beneath the water level and the Calvert strata occupy all the lower portion of the exposed sections of the river bluffs.

I. *Section below mill dam on Marricossick Creek one mile north of Bowling Green.*

			Feet
Miocene.	Calvert	**Light greenish-gray sandy clay**	10
		Dark green sandy clay containing casts, especially abundant near base, *Turritella plebeia*, *Venus*, etc.	8
		Total	18

The top of the section is about on a level with the top of the dam. The base is about 60 feet below the plain on which Bowling Green stands.

II. *Marricossick Creek, at Travers mill, three and one-half miles northeast of Milford.*

Just below the east end of the dam there is a 5-foot exposure of greenish-gray clay containing casts of *Turritella plebeia, Venus, Dosina,* etc. It belongs to the Calvert formation. In the compact clay in the bed of the stream there are a few small potholes.

III. *Marricossick Creek, Smoot's mill. The dam is on the branch entering the creek just above the mill.*

Just below the north end of the bridge 8 or 10 feet of greenish colored clay are exposed, containing Miocene casts, principally *Turritella plebeia,* and some diatoms. The elevation is a little less than 100 feet above sea level. Below the tail race at the mill similar materials are exposed.

Miocene marl occurs four miles northwest of Walkerton on the farm of G. Murdock, and was formerly dug. Specimens of the marl can be seen about the old marl pit. The shells are so weathered that only *Plicatula, Pecten, Discinisca, Ostrea, Chama,* etc., could be recognized. This marl appears in many small ravines on this and adjoining farms.

In some ravines on the farm of T. M. Barefoot, three miles northeast of Walkerton, great quantities of shell marl have been dug. The marl is not being used at present because of the scarcity of labor. The marl, as exposed, is about 25 feet in thickness. The upper portion is the same bed as described on farm of G. Murdock, consisting of rotten shells forming a lime sand in which *Plicatula* is unusually abundant. Beneath comes yellow and blue (where unweathered) sand in which there is a rather varied fauna with shells preserved.

IV. *Walkerton.*

Just below the mill dam there is a thickness of 17 feet of diatomaceous earth exposed. This lies below the shell marl described as occurring 4 miles northwest and 3 miles northeast of Walkerton. From roadside exposures observed near Walkerton it seems that there is a thickness of perhaps 30 feet of yellow or blue sand between the diatomaceous earth and the shell marl.

V. *Mattaponi River between Walkerton and West Point.*

For several miles below Walkerton the diatomaceous earth appears in the banks frequently showing a thickness of 20 feet. The Pleistocene covering is thin and consists of brown to gray sand with some small pebbles. At White Oak Landing (right bank) the diatomaceous earth is replaced by a blue earth which is intermediate between diatomaceous earth and blue sand. At Mantapike Landing (left bank) the bluff is about 20 feet in height and extends for some distance below. Although largely concealed by vegetation the lower part of the bluff is seen to consist of Miocene buff sand.

At Newington (left bank of river) there is a bluff 18 to 20 feet in height with some Miocene buff sand outcropping at the base. Between Wakema, right bank (Frazier's Ferry), and Indian Town there is a high bluff about 75 feet in height which is said to be the highest bluff on the river. Landslides have obscured part of it but it seems that at least 50 feet consists of Miocene sand which is buff above (where weathered) and blue below. At Courthouse Landing about 2 miles from King and Queen Courthouse the bluff is about 45 feet in height. Blue Miocene earth extends from water to a height of about 5 feet. Between Courthouse Landing and Clifton several low bluffs with blue Miocene earth appear while the exposure at Clifton Landing (left bank) shows the blue Miocene earth very well. Below Clifton Landing no bluffs exposing Miocene were seen on the Mattaponi. A few low bluffs show Pleistocene strata.

VI. *Section along road six and one-half miles southeast of Ashland.*

			Feet
Pleistocene		Surface loam yellow and mottled	4
		Band of clay with small pebbles	1
		Brown iron sand with some clay	5
		Pebble layer (pebbles from 1 to 3 inches in diameter)	1-3 in.
Miocene.	**Calvert**	Drab clay with many fossil casts, blue when fresh (exposed)	10
		Total	20¼

SECTIONS IN THE PAMUNKEY AND CHICKAHOMINY RIVER VALLEYS.

There are few good exposures of the Calvert formation along either of these streams due to the low bluffs and the swamps that border the streams throughout so great a portion of their courses. Enough exposures are known, however, to prove the continued distribution of the Calvert along their valleys in Hanover, Henrico, New Kent, and Charles City counties.

At the road crossing of Stony Run, 4½ miles southeast of Ashland, 10 feet of fossiliferous blue clay belonging to the Calvert is exposed resting directly on the crystalline rocks. One mile south of that point at crossing of Ashland-Richmond road and the Chickahominy River similar material about 15 feet in thickness appears on the north side of the stream between the crystalline rock and Pleistocene gravels and sand. On same road 1 mile south of the Chickahominy River the Calvert formation is again exposed.

The Calvert, consisting of drab to blue clay and sandy clay, is exposed in many places along Totopotomy Creek, in the valley of the Chickahominy near Mechanicsville, and near Gaines Mill.

Section in railroad cut and river bank at Ramancoke on the Pamunkey River, four miles west of West Point.

			Feet
Pleistocene		Brown and mottled (red and drab) clay loam interbedded with many layers of coarse sand containing thin bands of pea gravel........	20-25
Miocene.	Calvert	Buff-colored, fine-grained sand with certain portions slightly indurated..................	30-35
		Blue sand containing extremely fragile fossils	25
		Total..............................	85

SECTIONS IN THE JAMES RIVER VALLEY.

The Calvert formation is exposed in few places along the James River though it can be frequently seen along the small tributaries. In Richmond it is exposed in numerous places but best along Shockoe Creek near the Richmond Locomotive Works. It consists of more or less impure diatomaceous earth overlying Eocene greensand and overlain by Pleistocene gravels and loam. The total thickness exposed is 40 to 50 feet. Many species of diatoms have been described from this bed and it contains also some imprints of molluscan shells and vertebrate remains. Most remarkable, however, are leaf remains found in the upper portion.

Mr. E. W. Berry has recently described[a] 14 species of plants from this bed of which 6 are new.

At 18th and Venable Streets in Richmond there is a layer of impure glauconitic sand included in the Calvert drab clay. At its greatest thickness the lenslike layer is 4 feet thick. The glauconite has undoubtedly been derived from the Eocene which outcrops in the vicinity.

At Howlett House Bluff the Calvert is well exposed as given on a preceding page and in several places near Chester. In the main it consists of blue sandy clay with few fossil impressions.

Calvert blue sandy clay overlying Eocene greensand is exposed in many places along Bailey's Creek and on the James River in the vicinity of City Point.

Section on right bank of James River just below Blairs Wharf, eleven and one-half miles below City Point.

			Feet
Pleistocene		Brownish-yellow stratified sand containing small amount of clay in certain layers, also a few thin iron bands and small pebbles.....	19
Miocene.	Calvert	Drab exceedingly tough clay sharply separated from sand above. Clay near base is decidedly blue. No fossils. Exposed to water........	9
		Total........	28

SECTIONS IN THE APPOMATTOX RIVER VALLEY.

The Calvert formation outcrops in many places along the tributaries of the Appomattox River and some of these localities are famous because of the great numbers of fossils present. At Petersburg the formation outcrops in the valley of Lieutenant Run. Diatoms are abundant in certain portions of the bed and have been described by microscopists. Numerous molluscan fossils have also been obtained here as shown by the list given on another page. One of the best sections exposed is the one that follows:

Section in ravine near New Reservoir on Lieutenant Run.

			Feet
Pleistocene		Coarse cross-bedded and laminated buff to ferruginous-brown sand with a rather persistent band of ferruginous sandstone ½ to 1 foot in thickness near base................	15
Miocene.	Calvert	Blue sand containing fossil shells. *Venus tridacnoides* and *Turritella* especially abundant; shells very rotten	5
		Similar blue material without fossils........	8
		Total..............................	28

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[a] Jour. Geol., vol. xvii, pp. 19-30.

On Poo Run just east of "The Crater", marl is said to have been dug a great many years ago for fertilizing purposes. Fragments of shells can be picked up in the fields but no exposures of marl can now be seen, although a short distance northeast from "The Crater" nonfossiliferous Miocene buff sand is exposed.

Shell marl belonging to the Calvert formation is found and has been dug at Tinsberry Creek just east of the railroad crossing. It is said to be of a very fine quality for fertilizing purposes as the shells are greatly decayed and disintegrate soon after it is spread on the surface. Thus it acts very quickly. The practice is to use about 250 bushels to the acre if there is considerable vegetation on the land. If not, less is used, otherwise the land would be ruined. Shell marl has also been dug in numerous places on Ashton Creek and its tributaries.

Four miles southwest of Bermuda Hundred yellow ochre was formerly dug. The material was derived from the upper strata of the Calvert formation. The ochre bed is said to be about 7½ feet thick on an average. Specimens of prepared ochre and ochre from a pile near the mouth of one tunnel were seen but none of it can now be observed in place. It was worked by tunnels driven into the hill to a distance of 30 to 35 feet from the surface. Red ochre was manufactured by burning the yellow raw material. It is said to have been more profitable to burn the ochre than to dispose of the natural yellow material.

Shell marl is poorly exposed along Marl Branch three-quarters of a mile southwest of Carson and has been dug for fertilizing purposes along the base of the hill near the branch. The shells occur in a matrix of gray calcareous sand. The following forms were recognized: *Pecten, Venus, Crepidula, Arca, Cardita, Venericardia, Astarte* (2 species), *Glycymeris, Turritella, Crassatellites, Balanus,* worm tube, *Dentalium, Corbula* (?) Bryozoa, etc., etc.

The Choptank Formation.

(NOT RECOGNIZED IN VIRGINIA.)

The Calvert formation is succeeded in Maryland by deposits of sandy clays, sand, and shell marl that are much more arenaceous than the Calvert below or the St. Mary's above. The beds composing this formation decline in thickness toward the Potomac River and are not known with certainty to occur on the southern side of the valley in Virginia. The deposits hitherto described as Choptank in the Nomini Bluffs are now known, from a more exhaustive study of both the stratigraphy and paleontology, to belong to the Calvert formation. It is possible that the Choptank may be represented, as it gradually thins out, in the low country lying between the known outcrops of the Calvert and St. Mary's formations but buried beneath the cover of Pleistocene formations. No outcrops or well borings occur in this intermediate region and as no evidence is afforded for the presence of the formation it has been considered in the mapping as having finally thinned out north of the Virginia shore of the Potomac.

The St. Mary's Formation.

Name.—This formation receives its name from St. Mary's County, Maryland, where highly fossiliferous beds of this age are found and where the lithologic characters of the formation are also well shown. It was so named by G. B. Shattuck in 1902.[a]

Stratigraphic relations.—The St. Mary's formation overlies the Calvert formation unconformably except in the western portions of Sussex and Southampton counties and the eastern part of Greenesville County, where the St. Mary's rests directly on the crystalline rocks due to its transgression by the Calvert formation. This relation exists in North Carolina where the St. Mary's is the oldest Miocene formation present. Along the Roanoke River it unconformably overlies either the crystalline rocks of the Piedmont Plateau or the strata of the Lower Cretaceous. In the southeastern portion of the State the St. Mary's formation is unconformably overlain by the Yorktown deposits which constitute the latest Miocene formation of the State. In the region of outcrop the St. Mary's, like the Choptank, is frequently concealed from view over the divides and in the valleys of the larger streams by thin deposits of Pleistocene materials which rest unconformably upon the eroded surface of the St. Mary's strata.

Lithologic character.—In lithologic character the St. Mary's formation is very similar to the Calvert except that deposits of diatomaceous earth are lacking. Dark blue to bluish-black compact clay is a very common constituent, while layers of sand and shell marl such as occur in the Choptank formation are of secondary importance. The sands and clays are frequently rich in calcareous matter from the disintegrated molluscan shells. The shell marl has been employed for agricultural purposes in a great many places. In the vicinity of Williamsburg the St. Mary's formation contains considerable glauconitic sand irregularly distributed through the beds of yellow and buff quartz sand. Professor W. B. Rogers described this occurrence in a letter to the editor of the Farmer's Register dated June 26, 1834, and expressed himself as hopeful that other localities might be found in that region which would furnish as good greensand for fertilizing purposes as that of the New Jersey Cretaceous deposits.

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[a] Science, Vol. xv, 1902, p. 906.

Strike, dip, and thickness.—The strike of the St. Mary's formation is almost due north and south throughout Virginia but north of the Potomac River in Maryland the strike gradually changes to a northeast-southwest direction. The dip of the strata is to the east at about 10 feet to the mile. The maximum thickness of the formation is about 150 feet although this is attained only after the formation disappears beneath the tide, the outcropping portion of the formation being somewhat thinner.

Paleontologic character.—The St. Mary's formation is very rich in fossil remains as in the case of the other Miocene formations, the forms constituting an extremely varied marine fauna, essentially molluscan in character, although containing representatives of nearly all the leading groups of animals from the Protozoa to the Mammalia. The only plants thus far recognized are a few diatoms although there is no doubt but that a careful examination of the sands and clays would show the presence of a large number of diatom species. The St. Mary's formation is found in Westmoreland, Richmond, Northumberland, Lancaster, Middlesex, Gloucester, James City, York, Surrey, Isle of Wight, Nansemond, Sussex, and Southampton counties. Along the Potomac River it appears first in the lower part of Westmoreland County; along the Rappahannock River in the vicinity of Bayport; between the York and James rivers in several stream cuttings west of Williamsburg, and along the James River in many excellent exposures at Dillards Wharf, Claremont, Schmidt's Bluff, etc.; in numerous exposures along the Blackwater and Nottoway rivers in Isle of Wight, Southampton, and Nansemond counties; and in frequent exposures along the Meherrin River both in Virginia and North Carolina.

DETAILED SECTIONS.

SECTIONS EXPOSED IN SMALL STREAMS ON "NORTHERN NECK."

The St. Mary's formation is exposed in numerous places on the peninsula between the Potomac and Rappahannock rivers. The exposures seldom show more than a few feet of Miocene blue sand outcropping beneath the Pleistocene cover.

One-half mile north of Litwalton where the road crosses the stream there is a very good exposure of Pleistocene brown sand about 25 feet in thickness. The sand contains a great quantity of black grains, principally magnetite. About one-quarter mile farther north near the mill dam the St. Mary's outcrops beneath an ironstone about 1 foot in thickness, forming the base of the Pleistocene, which in this region is 68 feet thick. The Miocene consists of fine buff sand containing many mica flakes.

On the north side of the dam at Chinn's Mill on Lancaster Creek, 3½ miles north of Litwalton sandy drab clay belonging to the St. Mary's formation is exposed.

Section exposed on south side of the mill pond at Union Mills, one mile north of Downings and two miles south of Farnhams.

		Feet
Pleistocene or Recent	Brown sandy loam	
Miocene. St. Mary's	Shell bed consisting principally of *Melina maxillata* with some specimens of *Glycymeris*	8-13 in.
	Brown sand..........................	14-16 in.
	Shell bed principally composed of *Melina maxillata*, some specimens of *Pecten* and *Discinisca*......................	15 in.
	Sand filled with upright worm tubes....	8 in.
	Shell bed composed of innumerable small Pelcypods, in matrix of sand....about	3
	Total............................	13⅓

SECTIONS EXPOSED IN RAPPAHANNOCK RIVER VALLEY.

The St. Mary's formation outcrops in many places along the lower course of the Rappahannock River and admirably reveals the lithologic characteristics of the formation. Fossiliferous beds are numerous and have yielded a great variety of species.

I. *Section right bank of Rappahannock River, one-quarter of a mile below Jones Point.*

		Feet
Pleistocene	Red gravelly sand with iron crust at base..	10
Miocene. St. Mary's	Red and yellow sand grading down into greenish-gray sand	24
	Red and yellow sand slightly indurated in places	5
	Yellow and greenish-gray loose sand........	17
	Drab clay thinly interlaminated with sand layers	25
	Greenish-gray fossiliferous sand..........	8
	Total..............................	89

Just above Bayport Wharf there is a well exposed cliff about 90 to 100 feet high, showing essentially the same kinds of materials given in preceding section, with the exception of the fossiliferous bed which is wanting. The same prominent laminated clay layer is present but has perhaps dipped a few feet lower than in the section described above.

II. *Section right bank of Rappahannock River one-half mile below Bayport.*

			Feet
Pleistocene		Loam grading into sand and gravel ....about	15
Miocene.	St. Mary's	Greenish-gray sand mottled with yellow..about	15
		Total............................	30

III. *Section right bank of Rappahannock River, one-half mile above Punch Bowl Point, and about two and one-half miles below Bayport.*

			Feet
Pleistocene		Loam grading down into drab clay with a thin band of pebbles at base....................	11
Miocene.	St. Mary's	Greenish-gray argillaceous sand with many fossils, slightly indurated in places near top, the cement being iron oxide. Most numerous species are *Melina maxillata, Arca centeneria*, and *Vermetus virginicus*..........	6
		Total..............................	17

The exposure with essentially the same strata extends for about 200 yards along the shore. The most abundant species of fossils are *Melina maxillata, Arca centenaria, Vermetus virginicus, Ostrea, Turritella variabilis, Panopea goldfussi, Crassatellites turgidulus* (?), *Arca staminea, Pecten madisonius, Ecphora quadricostata, Chione latilirata, Discinisca lugubris, Anomia aculeata.*

IV. *Section right bank of Rappahannock River at Waterview Wharf.*

			Feet
Pleistocene		Sand, clay and loam........................	12
Miocene.	St. Mary's	Greenisn-gray sand. An undulating, slightly rusty layer occurs about 3 feet above base containing casts of Miocene shells in a poor state of preservation. In places some of the calcium carbonate remains	6
		Total..............................	18

Along the shores of Urbanna Creek and in the bluff along the river between Urbanna Creek and Nelson's Wharf in West Urbanna the St. Mary's Miocene is exposed. It consists of a buff to gray sand in which there is a bed of shell marl containing a wide variety of molluscan species. The bank is about 18 feet high of which the upper 3 to 6 feet consists of Talbot sand. The shell layer varies in thickness but is rarely thicker than 2 feet. The sand also carries some shells irregularly distributed through the mass.

V. *Section at Burham's Wharf on the Rappahannock River.*

			Feet
Pleistocene		Brown loamy sand..........................	5½
		Stratified brown and yellow sand with a few pebbles and cobbles (4 inches in diameter) at base..................................	16
Miocene.	St. Mary's	Greenish-gray slightly argillaceous fine sand, blue in color near base, where unweathered, much stained with iron and containing numerous casts and moulds of fossils and a few shells of *Melina maxillata*................	15
		Total..............................	36½

SECTIONS EXPOSED IN THE CHICKAHOMINY AND YORK RIVER VALLEYS.

The St. Mary's formation is not well exposed in many places between the Rappahannock and James rivers yet frequently enough to determine its continuity.

I. *Section on left bank of Chickahominy River at Lanexa.*

			Feet
Pleistocene		Reddish-yellow clay (in some places decidedly red and in other places mottled)....	10½
		Thinly laminated drab and pink clay separated by thin films of fine sand........	11
		Laminated, mottled (pink, drab, and yellow) clay	27
		Greenish-gray clay containing carbonaceous matter	2
Miocene.	St. Mary's	Loose greenish-gray sand..................	3
		Shell bed, shells in matrix of sand similar to above layer. The shells consist almost entirely of *Pecten eboreus* and *Pecten jeffersonius*. Besides these there are a great many specimens of *Ecphora quadricostata*, *Pecten clintonius*, *Crassatellites*, *Glycymeris*, *Venericardia granulata*, *Astarte*, *Dentalium*, *Discinisca* and *Dosinia*. All except the pectens and ecphoras are exceedingly rotten	3-7
		Light-colored buff to gray sand, few fossils	7
		Blue sand very compact, few fossils (exposed to railroad track)................	16
		Total..............................	83½

Near the base of the above section the blue sand contains numerous rounded nodules, many of which look like dumb-bells. Some of these enclose a *Pecten* shell, and are 1½ feet long.

In the old cut just above the shell bed the sand is filled with casts of *Chama* while the upper part of the shell bed is quite firmly indurated in places and some of the shells are filled with calcite crystals. The shell bed here contains besides the fossils already named, *Phacoides, Ostrea, Fissurella,* and *Venus.*

The Pleistocene in the old cut contains near its base in one place a ledge of iron sandstone about 10 inches in thickness. The railroad track is about 25 feet above the river. There is no good exposure but it seems that everything from railroad track to the water consists of loose buff sand.

II. *Section right bank of York River at Mount Folly.*

			Feet
Pleistocene		Brown and mottled loam becoming sandy toward base	15
		Brown sand in places indurated by iron to form quite firm sandstone 10 feet thick	15
Miocene.	St. Mary's	Buff sand containing considerable drab clay	15
		Buff sand containing grains of magnetite	25
		Shell layer containing numerous specimens of ***Melina maxillata, Pecten jeffersonius,*** var. *septenarius; Ostrea compressirostra;* somewhat indurated	2
		Light-colored buff sand	10
		Greenish-blue fine sand	2
		Total	84

SECTIONS IN THE JAMES RIVER VALLEY.

The St. Mary's formation is well exposed in several places in the James River bluffs where the fossiliferous strata have long been known as excellent collecting grounds.

I. *Section right bank of James River, one and one-quarter miles above Claremont Wharf (just below Old Claremont Wharf).*

			Feet
Pleistocene		Yellow sand with some loam at top and pebble band at base	16
Miocene.	St. Mary's	Shell bed, shells in matrix of yellow sand, forms varied and well preserved	12
		Yellow sand without fossils	15
		Shell layer, shells in matrix of blue sand	10
		Blue sand grading into overlying stratum containing numerous specimens of ***Turritella.*** Exposed to water	6
		Total	59

II. *Section right bank of James River, just above mouth of Sunken Marsh Creek, two miles below Claremont Wharf.*

			Feet
Pleistocene		Loamy yellow sand with a few thin clay lenses	17
		Bands of small pebbles	4⅓
		Cross-bedded sand with many small pebbles and a few rounded cobbles at base	14
Miocene.	St. Mary's	Buff sand	8
		Fossiliferous layer containing many species, of which *Pecten* is by far the most abundant; shells embedded in matrix of yellow sand	11
		Blue clayey sand, slightly fossiliferous	14
		Blue clayey sand, highly fossiliferous with *Turritella* predominating	10
		Blue clayey sand without fossils	5
		Blue clayey sand with fossils distributed through it, *Turritella* abundant, exposed to water	8
		Total	91-⅓

One-half to three-quarters of a miles above Dillard's Wharf the upper shell bed described in the previous sections increases in thickness to about 20 feet. The lower shell bed with blue sand matrix remains about the same. Near the wharf a great deal of indurated shell material consisting largely of pectens is strewn on the beach but was not seen in place. In this material a fossil echinoid was found.

III. *Section at Dillard's Wharf on the James River.*

			Feet
Pleistocene.	Talbot	Yellowish-red loam	15
Miocene.	St. Mary's	Shell marl	12
		Light-colored sands with thin strata of shells consisting of *Pecten*, *Venus*, etc	4
		Sandy clay, exposed	5
		Total	36

IV. *Section right bank of James River, eight and one-half miles below Claremont Wharf at Schmidt's Bluff.*

		Feet
Pleistocene	Compact red, yellowish-brown, and mottled (red and yellow) sand, looser at base	17
	White sand with white to mottled (white and pink) clay	8

			Feet
		Band of small pebbles in matrix of white sand containing some white and pink clay	4
		Pink to yellow to gray sand containing considerable clay	8
		Sandy yellow to gray clay	6
Miocene.	St. Mary's	Layer of indurated shell marl with *Pecten* the dominant genus	5½
		Shell layer	20
		Gray sand with few fossils	5
		Blue clayey sand slightly fossiliferous (to water)	7
		Total	80½

At Rocky Point, opposite the west end of Jamestown Island, beneath a covering of Pleistocene about 18 to 20 feet in thickness, there is a 12-foot indurated fossiliferous stratum. The shells are firmly consolidated, forming a hard rock which has fallen in great masses and covers the beach. The calcareous material has been removed in some cases forming a porous rock composed of sand molds and casts. *Melina, Pecten eboreus* (?) and *Balanus* are the common forms. Beneath the hard layer there is a bed of loose buff sand containing some fossils. The shell bed seems to represent part of the thicker shell layer described in previous sections while the buff sand represents the blue slightly fossiliferous sand exposed at the preceding localities.

V. *Section right bank of James River just below Scotland Wharf.*

			Feet
Pleistocene		Yellowish-brown sand with some small pebbles	13
Miocene.	St. Mary's	Shell marl, the same layer as that at Rocky Point, though less firmly indurated and not so thick. Fragments of this rock strew the beach. Where the rock is not consolidated the shells are present, but are exceedingly rotten	7
		Buff sand with few fossils	2
		Material concealed by wash, to water	10
		Total	32

In the right bank of the James River, ¾ mile above mouth of Cobham Creek, the Miocene shell bed which is so prominently exposed in the Claremont and Dillard's Wharf bluffs and at Rocky Point and Scotland, outcrops, reaching a height of about 12 feet above the water. Only the lower part of the bed seems to be present and the entire thickness is only about 5 feet. The Pleistocene cover consists almost entirely of sand with few small pebbles and some drab clay. Beneath the shell stratum a little buff sand appears but most of it is covered by wash. The marked unconformity between the Miocene and Pleistocene is shown one quarter of a mile to the east of this bluff where the Pleistocene extends to the water, the Miocene being cut out. The bluffs are about the same height. In the second bluff the Miocene is probably just below the water as the shells are washed out during storms and thrown on the beach.

SECTIONS IN THE BLACKWATER RIVER VALLEY.

The St. Mary's formation is well developed in the valley of Blackwater River where it contains extensive beds of shell marls which have been dug in many places for fertilizing purposes. The shells occur in a matrix of blue sand or sandy clay and are usually in a good state of preservation. *Mulinia congesta* is especially abundant and in certain layers is practically the only fossil present. Marl pits were visited one-quarter mile southwest of McClelland, one-half mile northwest of Raynor, at Raynor, and 3 miles northwest of Zuni. Numerous other abandoned pits occur in the same region.

I. *Section left bank of Blackwater River at Old Seine Hole Landing, about one and one-quarter miles north of Zuni (by water).*

			Feet
Pleistocene		Sand, yellowish	6
Miocene.	St. Mary's	Blue fossiliferous sand weathering to yellow, containing *Crepidula aculeata var. costata, Turritella variabilis, Arca centenaria, Glycymeris subovata, Pecten clintonius, Phacoides anodonta, Plicatula marginata*	6
		Total	12

II. *Section of left bank of Blackwater River, about one-half mile north of Zuni.*

			Feet
Pleistocene		Yellowish sand	6
Miocene.	St. Mary's	Yellow to blue sandy marl carrying abundant specimens of *Mulinia congesta*	10
		Total	16

At Zuni in an old well or pit near the pumping station bluish sand and marl were exposed about 4 feet below the surface. *Crucibulum grande. Polynices heros, Turritella variabilis, Mulinia congesta* and *Panopea reflexa* are abundant forms present in the marl.

III. *Section in ravine, about two and one-half miles south of Zuni near old saw mill.*

			Feet
Pleistocene		Yellow and reddish mottled sandy clay......	4-6
Miocene.	St. Mary's	Weathered yellow sandy marl with few or no shells	2-3
		Compact fine-grained sandy and argillaceous marl containing few fossils................	4-6
		Total..............................	15

IV. *Section right bank of Blackwater River, six miles by road south of Zuni.*

			Feet
Pleistocene		Yellowish sand	6
Miocene.	St. Mary's	Yellowish (weathered) sandy marl, fossiliferous	4
		Blue sandy marl, slightly glauconitic, highly fossiliferous	5
		Total...............................	15

V. *Section left bank of Blackwater River, about one and one-half miles below Blackwater Bridge.*

			Feet
Pleistocene		Yellow to white sand.......................	6
		Drab sandy clay...........................	6
Miocene.	St. Mary's	Bluish marl containing *Mulinia congesta*	4
		Total...............................	16

Between the above locality and Burdette there are a number of banks which show from 2 to 3 feet of marl similar to that in the foregoing section.

VI. *Section left bank of Blackwater River, about seven miles (by water) south of Zuni.*

			Feet
Pleistocene		Yellowish sand............................	6
Miocene.	St. Mary's	Bluish sandy fossiliferous marl. slightly glauconitic (?) and partially indurated, containing *Cadulus thallus*, *Dentalium attenuatum*, *Polynices heros*, *Turritella variabilis*, *Aroa centenaria*, *Astarte undulata*, *Chama congregata*. *Crassatellites undulatus*, *Glycymeris subovata*. *Modiolus ducatelii*. *Panopea reflexa*, *Pecten clintonius*, *P. jeffersonius*, *Phacoides anodonta*, *Venericardia granulata*	8
		Total...............................	14

VII. *Section right bank of Blackwater River, seven and one-half miles (by water) south of Zuni.*

			Feet
Pleistocene		Yellow sand	6
Miocene.	St. Mary's	Yellow (weathered) to blue (unweathered) sandy marl carrying numerous specimens of *Mulinia congesta*	3
		Bluish sandy marl, somewhat glauconitic, and highly fossiliferous, containing *Crepidula aculeata* var. *costata*, *Crucibulum grande*, *Polynices heros*, *Turritella variabilis*, *Arca centenaria*, *A. incile*, *Astarte undulata*, *Glycymeris subovata*, *Margaritaria abrupta*, *Ostrea compressirostra*, *O. sculpturata*, *Panopea reflexa*, *Pecten clintonius*, *P. eboreus*, *P. jeffersonius*, *P. jeffersonius* var. *septenarius*, *Venericardia granulata*	5
		Total	14

VIII. *Section right bank of Blackwater River, eight and one-half miles (by water) below Zuni.*

The bluff at this point is one of the highest along the Blackwater River.

			Feet
Pleistocene		Yellowish sand	about 13
Miocene.	St. Mary's	Yellowish weathered sandy marl, fossiliferous, containing *Arca incile*, *Glycymeris subovata*, *Mulinia congesta*, *Ostrea compressirostra*, *O. sculpturata*, *Pecten jeffersonius*, *P. jeffersonius* var. *edgecombensis*, *Venus rileyi*	20
		Concealed, probably blue marl	12
		Total	45

IX. *Section left bank of Blackwater River about three miles (by water) south of Burdette.*

			Feet
Pleistocene		Yellowish sand	12
Miocene.	St. Mary's	Light blue compact sandy clay weathering to yellow and containing impressions of shells similar to those occurring in upper part of marl beds elsewhere in this region	12-15
		Total	27

A similar section was observed about 1½ to 2 miles (by land) north of Franklin.

X. *Section right bank of Blackwater River at wharf at Franklin.*

			Feet
Pleistocene		Superficial mantle, probably yellow sandy clay	6
Miocene.	St. Mary's	Light olive green compact sandy clay showing fossil impressions and casts of *Mulinia congesta* and *Yoldia laevis*	4-6
		Total	12

A similar section is exposed on the left bank of the Blackwater River about one-eighth mile below the wharf at Franklin.

XI. *Section left bank of Blackwater River, about two and one-half miles below Franklin.*

			Feet
Pleistocene		Yellow sand	2-3
Miocene.	St. Mary's	Blue clay with fossil impressions	2-3
		Total	6

XII. *Section left bank of Blackwater River, two and three-quarter miles below Franklin.*

			Feet
Pleistocene		Buff sand	3
Miocene.	St. Mary's	Drab to yellow sandy clay	4-5
		Weathered blue sandy clay	3
		Total	11

XIII. *Section right bank of Blackwater River, about two and one-half miles below South Quay.*

			Feet
Pleistocene		Yellowish sand	3-4
Miocene.	St. Mary's	Bluish-green weathering to yellow compact sandy clay with fossil impressions	3-4
		Bluish-green compact sandy clay similar to that at Franklin but less weathered, and containing *Mulinia congesta*, and *Yoldia laevis*	4-6
		Total	14

On the left bank of the Blackwater River at Ellis Wharf about four miles below South Quay, Miocene clay is exposed in several places. Occasional exposures of sandy fossiliferous marl occur on either side of the river for several miles below this point.

XIV. *Section left bank of Blackwater River just below Cobbs Wharf, about seven miles below South Quay.*

			Feet
Miocene.	St. Mary's	Yellowish sand	6
		Bluish-green sandy clay, slightly fossiliferous	6
		Total	12

SECTIONS IN THE NOTTOWAY RIVER VALLEY.

Although high bluffs are not common along the Nottoway River yet nevertheless there are numerous exposures of Miocene strata in the comparatively low river banks where the stream has cut through the thin covering of Pleistocene gravels, sands and clays. The St. Mary's is the only Tertiary formation exposed along the Nottoway River. It consists mainly of blue sand or sandy clay in which are occasional lenses of shell marl.

I. *Section in well at lumber mill two miles southeast of Sussex Courthouse.*

			Feet
Miocene.	St. Mary's	Yellowish sand and sandy clay	8-10
		Bluish-green sandy marl	2-4
		Total	14

At the base of Marl Hill, a bluff about 70 feet high on the right bank of the Nottoway River 2½ miles south of Lumberton, there is a good marl bed exposed 15 to 20 feet above the water. The lower portion of this bed is blue in color while the upper weathered part is light yellow.

Yellowish partially indurated sandy marl belonging to the St. Mary's formation outcrops in the right bank of the Nottoway River at Carey's Bridge, about 1½ miles west of Sebrell.

On the right bank of the Nottoway River about 4 miles (air line) above Courtland Bridge, there is a bank 60 feet or more in height, in which the St. Mary's formation is exposed. Marl was dug from the lower part of this bank some years ago but it is now concealed by cliff débris.

On the left bank of the Nottoway River about one-half to three-quarters of a mile above Cypress Bridge, bluish-green sandy marl outcrops about 5 feet above the water. The upper and lower portions of the bluff are concealed by vegetation and talus.

II. *Section west bank of the Nottoway River, about one-eighth mile above Cypress Bridge.*

			Feet
Pleistocene		Yellow sand	5
		Drab laminated clays with yellow sand	10
		Coarse white and yellowish sand	4
Miocene.	St. Mary's	Bluish sandy clay, slightly fossiliferous	1+
		Total	20

At Darden's Mill about 3-¾ miles southwest of Courtland, there is an exposure of blue sandy marl with some glauconite (?) in which are *Venus rileyi, Crassatellites, Pecten, Isocardia, Venericardia granulata, Glycymeris, Astarte, Ostrea, Arca, Chama, Crepidula, Polynices,* etc.

III. *Section right bank of the Nottoway River, about two miles below the S. A. L. Railroad Bridge.*

			Feet
Pleistocene		Reddish brown sand	4-5
Miocene.	St. Mary's	Yellowish to greenish sandy marl, fossiliferous	4-5
		Total	10

IV. *Section left bank of the Nottoway River at Sycamore about 2½ to 3 miles below the S. A. L. Railroad Bridge.*

			Feet
Pleistocene		Buff sandy soil	2
		Reddish yellow sand	3-4
Miocene.	St. Mary's	Dark greenish-gray sandy marl, containing a large number of well-preserved fossils	6
		Total	12

V. *Section left bank of the Nottoway River about one-half mile below Sycamore.*

			Feet
Pleistocene		Drab sandy soil	2
		Coarse white and gray sand	2-4
		Yellow to greenish-yellow sand with an increasing proportion of glauconite grains from the top downward	4-5
Miocene.	St. Mary's	Yellowish-brown to blue sandy marl, glauconitic, and highly fossiliferous, containing *Crepidula aculeata* var. *costata, Dentalium attenuatum, Ecphora quadricostata, Polynices heros, Arca incile, Glycymeris subovata, Mulinia congesta, Ostrea compressirostra, O. sculpturata*	4-5
		Total	16

VI. *Section left bank of Nottoway River about five miles below S. A. L. Railroad Bridge.*

			Feet
Pleistocene		Surface covering, not well exposed	4
Miocene.	St. Mary's	Blue sandy clay unfossiliferous	3-5
		Total	9

SECTIONS IN THE MEHERRIN RIVER VALLEY.

The St. Mary's formation is present in the valley of the Meherrin River from the vicinity of Emporia where the stream enters the Coastal Plain to its junction with the Blackwater River. Good exposures of the underlying strata are rare, however, as the river banks are in most places composed of recent alluvial material. In certain places the river is actively cutting the sides of the valley and Miocene strata outcrop beneath the surficial covering.

In the vicinity of Emporia there seem to be many isolated patches of St. Mary's strata lying between the Piedmont crystalline rocks and the Pleistocene reddish-yellow sands and sandy clays that are so extensively developed in that region. At the mill near Hitchcock shell marl containing *Mulinia congesta, Pecten, Venus, Leda, Polynices, Turritella, Dentalium, Ecphora, Ostrea,* etc., was encountered in two wells at a depth of about 25 feet from the surface. A short distance away granite outcrops showing the Miocene shell marl to be an isolated area deposited in a depression in the irregular surface of the crystalline rock floor. Shell marl was also encountered in a well at the saw mill of J. E. Mayes, 1½ miles north of Emporia. The marl, which contains specimens of *Pecten, Ostrea,* etc., occurs 10 to 12 feet from the surface.

I. *Section on Meherrin River about twelve miles southeast of Emporia (by wagon road).*

			Feet
Pleistocene (?)		Concealed	18 to 20
Miocene.	St. Mary's	Light drab or gray, in places greeenish-gray clay, having very little sand content at top but gradually becoming more sandy and grading into a light gray fossiliferous sand fine in texture. The fossils are present in the form of casts only and are characteristic Miocene species. About 7-9 feet above medium low-water near the base of the bed, the sand is indurated in places so that good specimens were obtained. The following forms were recognized: *Pecten, Dosinia, Fulgur* (?) *Turritella, Leda, Polynices* (?), *Panopea* (?), *Balanus,* etc.	about 33
		Total	53

In the field above this bluff, where the marl had been used for fertilizing purposes, fragments of *Pecten, Ostrea, Venus,* etc., were observed.

II. *Section on the Meherrin River about one mile above the S. A. L. Railroad Bridge.*

			Feet
Pleistocene		Yellowish loam and sand with a gravel band at base in which are boulders of quartz ranging in size up to 1 foot in diameter.......	10
Miocene.	**St. Mary's**	Bluish-green plastic clay with fragile fossil casts	2
		Total...................................	12

At a point on the Meherrin River about 1¼ miles below the S. A. L. Railroad Bridge at a sharp turn where the river cuts against a terrace some 15 feet above water level a marl bed is reported which was covered with water when that section of the river was examined. The marl has been used in the adjoining field and shells of *Pecten, Ostrea,* etc., may be seen scattered about.

III. *Section left bank of Meherrin River about two miles above Branch's Bridge, and about two miles (air line) below the preceding bridge.*

			Feet
Pleistocene (?)		Concealed	10
Miocene.	**St. Mary's**	Greenish-gray, compact, very fossiliferous sandy clay. The most numerous species is the small pelecypod *Mulinia congesta* common to the Miocene of this region. Many of the forms are very fragile and difficult to preserve. Exposed at high water.....................	4½
		Total..............................	14½

At the next cove on the right about one-half mile below the preceding the same bed is exposed in a similar bluff. A few forms not observed in the preceding section were noted. This place is about 1 mile (by water) above Branch's Bridge.

At Branch's Bridge which is about half way between the upper and lower S. A. L. Railroad bridges about 5 feet of rather dark greenish-gray sandy clay filled with fossils is exposed. The horizon is about the same as at the preceding localities and the material is similar.

IV. *Section on Meherrin River about one and one-half miles below Branch's Bridge.*

			Feet
Pleistocene		Concealed	10
		Gray to yellow ferruginous sand, argillaceous at top, becoming coarse and gravelly below with pebbles ranging in size up to 1 inch in diameter. One layer is made up of pebbles about the size of peas. This is streaked with pink and yellow. The whole is poorly exposed	15
Miocene.	**St. Mary's**	Light drab to almost black clay, somewhat laminated, the laminae due to fine sand partings, the whole more or less weathered, and showing occasional pink and yellow colors	11
		Dark green slightly arenaceous clay, very compact and plastic; barren of fossils	13
		Similar material containing characteristic Miocene fossils	22
		Total	71

This bluff is not very well exposed, because of landslides. The principal fossil found is the small pelecypod, *Mulinia congesta,* so characteristic of the Miocene of this region. Other forms present are *Turritella, Pecten. Ostrea, Dosinia,* etc.

On the left bank of the Meherrin River about 3 or 4 miles above the lower S. A. L. Railroad Bridge, four feet of greenish-blue sandy clay full of shells is exposed. The species present are the same as at Branch's Bridge.

V. *Section on the Meherrin River about three-quarters mile above the lower S. A. L. Railroad Bridge.*

			Feet
Pleistocene (?)		Concealed	25
Miocene.	**St. Mary's**	Reddish loamy clay	10
		Yellow fossiliferous sand, the principal shell being the small characteristic Miocene pelecypod *Mulinia congesta*, with a few *Pecten, Ostrea, Balanus*, etc	7
		Drab sandy clay	2
		Concealed	2
		Very rotten sandy shell marl, with *Pecten, Ostrea, Venericardia, Crepidula, Balanus*, etc	5
		Total	51

A few hundred yards below the above locality there is a better exposure of the marl. The material is less weathered and the matrix consists of the usual dark green argillaceous sand.

VI. *Section on the Meherrin River a few hundred yards below preceding section.*

		Feet
Pleistocene	Reddish yellow sandy clay and sand, laminated ....about	20
	Light gray or drab sandy clay mottled red with iron............................	10
Miocene. St. Mary's	Dark green sandy clay yellow in places, due to weathering, full of *Mulinia congesta* with a few other forms, *Pecten*, *Crepidula*, etc. ....about	36
	Similar material with many fossils. To water's edge...........................	5
	Total..............................	71

The Yorktown Formation.

Name.—The Yorktown formation has been so named because of the excellent exposure of the strata of this age in the prominent cliffs at Yorktown. The name was first employed in a formational sense by Clark and Miller[a] in 1906.

Stratigraphic relations.—The Yorktown formation overlies the St. Mary's formation conformably, although more careful work may reveal the presence of a slight unconformity. Such a break would help to explain the striking changes in physical environment between the two epochs of sedimentation as shown in the lithologic character of the strata. The Yorktown is for the most part concealed from view over the divides as well as in many of the larger valleys by unconformably overlying deposits of Pleistocene age.

Lithologic character.—The most characteristic materials of the Yorktown formation are beds of comminuted shells in which are contained numerous shells still entire but often more or less worn. These fragmental beds are well exposed along the York River below Yorktown at Fergussons Wharf, at Smithfield, at Benn's Church, at Suffolk, and near Reid's Ferry. They are usually quite firmly indurated by calcium carbonate obtained from the same or overlying marl beds. The appearance of the rock is not unlike the coquina rock of Florida, and doubtless the two have had a similar origin. The shell fragments are of various sizes and are mixed with greater or less amounts of sand, the materials closely resembling the modern beach shell deposits of the West Indies. It is probable that these fragmental layers accumulated in very shallow waters, the breaking and wearing of the shells being accomplished by the shore waves. In addition to these fragmental shell beds the Yorktown formation contains layers of sand, blue sandy clay, and also beds in which the shells are excellently preserved. Occasional grains of glauconitic sand are distributed through the beds of light-colored quartz sand. Since the formation of the Yorktown beds there has been considerable removal of the calcareous material by percolating waters, accompanied by a sinking of the overlying beds in many places, with the production of apparent unconformities. Occasionally the calcium carbonate removed from the upper beds has been deposited in the form of calcite crystals in the cavities of the shells of lower beds. Thus in many places nearly perfect internal casts of *Venus mercenaria* and other forms can be found composed of pure calcite.

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[a] Clay Deposits of the Virginia Coastal Plain. Geol. Series, Bull. No. 11, Geol. Survey of Virginia, 1906, p. 19.

Strike, dip, and thickness.—The strike of the Yorktown formation is in a north and south direction, while the normal dip of the beds is toward the east at the rate of a few feet to the mile. Locally, however, as seen especially at certain points in the Yorktown cliffs, the beds are horizontal or have a slight dip to the west. The shallow-water origin of the Yorktown beds accounts for the greater variability in comparison with the other Miocene formations which were for the most part accumulated in much deeper and more quiet waters. The thickness of the Yorktown formation is approximately 125 feet.

Paleontologic character.—As shown in the following sections the Yorktown formation contains a very rich and varied fauna. It is one of the most fossiliferous formations represented in the entire series of Atlantic Coastal Plain sediments and for years the beds exposed at Yorktown have been favorite collecting grounds for workers in Tertiary geology. While the fauna is distinctly molluscan in character, yet numerous vertebrate bones may be collected along the cliffs at almost any time. The recent discovery of the lower jaw of a walrus[a] in these beds is of especial interest.

Areal distribution.—The formation outcrops in Gloucester, James City, York, Warwick, Isle of Wight, and Nansemond counties. It has not been recognized in Maryland but may be present beneath the covering of Pleistocene materials on the Eastern Shores of both Maryland and Virginia. It is well exposed at Yorktown on the York River, at Smithfield on a tributary of the James River, and in the vicinity of Suffolk. The prevailing low topography in the region of outcrop of the Yorktown formation results in fewer exposures than in the case of the other Miocene formations. The formation has been traced southward into North Carolina where it is exposed in numerous places along the Chowan River and its tributaries.

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[a] Edward W. Berry and William K. Gregory. Amer. Jour. Sci., 4th ser., Vol. xxi, pp. 444-450, figs. 1-4, 1906.

DETAILED SECTIONS.

The Yorktown formation is well developed in the southeastern portion of the State in a belt extending southward from Gloucester County to the North Carolina line. In this region outcrops are numerous along many of the streams although only along the large estuaries can thick sections be observed. Fragmental shell beds which constitute the most distinctive lithologic features of the formation and distinguish it from any of the other Miocene formations of this region, outcrop in many places.

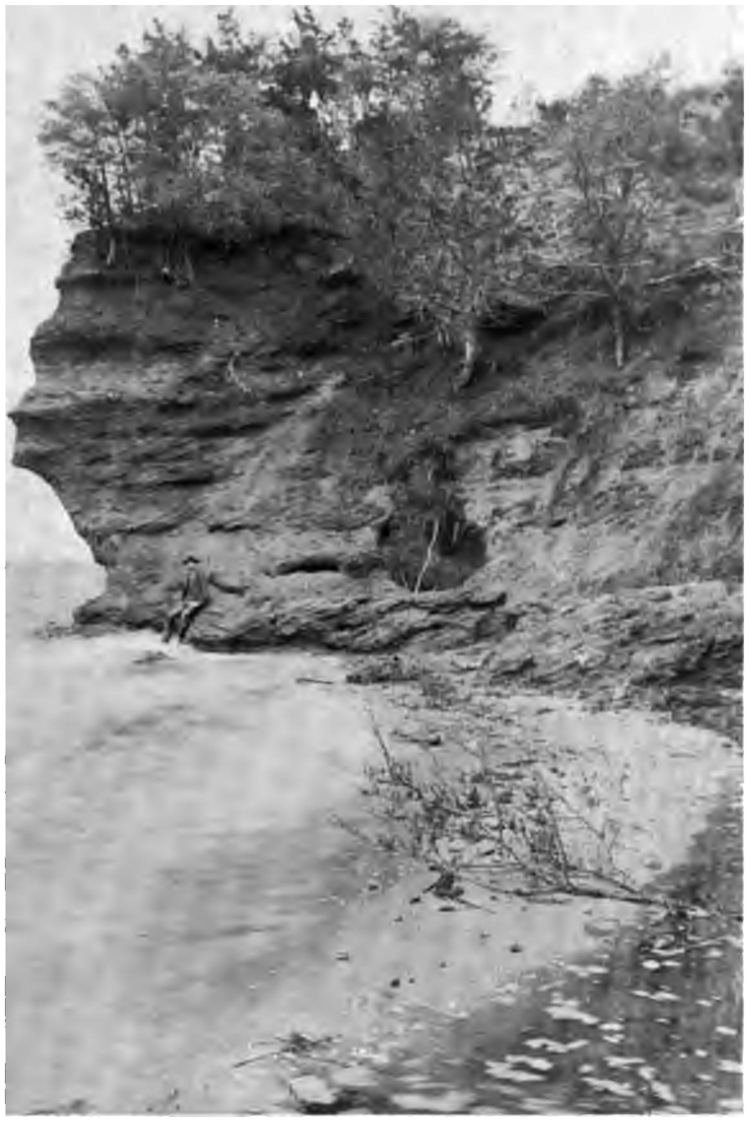
SECTIONS IN THE YORK RIVER VALLEY.

The Yorktown formation has its typical development in the region of Yorktown where extremely fossiliferous strata in the high bluffs have long been known to contain a great variety of well preserved fossils. No other locality in the State has furnished so many species or has received so much attention from paleontologists. The beds that outcrop in the vicinity of Yorktown extend through the adjoining counties and are exposed along many of the small streams.

At Stubb's Pond 1¼ miles northwest of Sassafras there is an exposure of about 8 feet of shell marl consisting principally of *Pecten jeffersonius* with numerous specimens of *Arca, Ostrea. Venus, Ecphora,* etc. The marl is overlain by about 30 feet of Pleistocene strata, the lower portion of which is rather sandy and contains some small pebbles but grades upward into a mottled red and drab clay.

On the valley slope of Poplar Spring Branch in Gloucester County there are poor exposures of Pleistocene and Yorktown materials. The lower 35 to 40 feet consists of drab clay and buff-colored Miocene (Yorktown) sand, the upper 30 feet of Pleistocene material similar to that described in the preceding note.

One-quarter mile north of Money a shell layer about 8 feet thick outcrops near stream.



Cliff near Yorktown, York River. Showing indurated calcareous beds of the Yorktown formation.

INDURATED CALCAREOUS BEDS OF YORKTOWN FORMATION.

Two and one-half miles southwest of Money shell marl about 10 feet in thickness is exposed along the roadside. *Chama congregata* is by far the most abundant fossil.

Three-quarters of a mile northwest of Clopton, a layer of shell marl outcrops along Carter's Creek just below the dam. In the vicinity of Gloucester Point there is considerable marl which before the war was used extensively on land, but little has been dug since then. At Bellefield on the south side of the river the same is true.

At the road crossing of Scimmino Creek mottled Pleistocene sand and clay about 30 feet in thickness overlies about 25 feet of Miocene (Yorktown) gray, iron-brown, and buff-colored sands in definite layers. In certain bands there is considerable clay present.

At the road crossing of Queen and Carter's creeks Miocene buff-colored sand containing fossils is exposed in the bottom of the valleys. The overlying Pleistocene is about 25-30 feet in thickness and consists of mottled (red, brown, and drab) clay grading downward into a cross-bedded sand.

At the road crossing near the head waters of King Creek, a shell layer 15 to 20 feet in thickness is poorly exposed along the roadside. The great quantity of *Pecten jeffersonius* and a few fragments of *Pecten clintonius* indicate that this layer is the same as that seen at the upper part of Bellefield and 1 mile below King's Mill on the James River. Some large species of *Cardium* were seen. Among the species represented at this locality are the following: *Arca centenaria, A. incile, Astarte concentrica, A. symmetrica, A. thisphilla* ?, *A. undulata, Cardita arata, Chama congregata, Crassatellites undulatus, Glycymeris subovata, Ostrea compressirostra, Pecten jeffersonius, P. madisonius, Phacoides anodonta, Venus rileyi, Crucibulum grande, Turritella variabilis.*

On Black Swamp Creek there is a shell layer exposed, consisting principally of casts, with some decayed shells. It resembles the layer occurring near the west end of Bellefield bluff.

Section exposed along the right bank of York River from King's Creek to Wormley's Creek.

			Feet
Miocene.	**Yorktown**	Sandy gray shell marl; shells generally large bivalves badly worn, sometimes fragmentary. Contains *Crepidula spinosa*, *Ostrea*, perhaps *O. virginica;* at Bellefield, *Melina maxillata, Pecten jeffersonius, P. clintonius, Glycymeris subovata, Venus tridacnoides, V. rileyi*, etc..	10
		Gray marl full of shells in some places becoming fragmentary; contains *Arca incile, Car-*	

	Feet
dita, Venus rileyi Ostrea sculpturata, Diplodonta elevata (?), *Glycymeris subovata, Dosinia acetabulum, Pecten jeffersonius*	14
Gray sandy and clayey marl. Contains *Crepidula, Venus*, etc., few and poorly preserved	14
Blue sandy clay becoming marly and stained brown by iron oxide. Contains *Yoldia lævis* (?), *Cytherea sayana, Pandora crassidens, Spisula delumbis, Dosinia acetabulum, Ensis, Scaphella, Dentalium dentale* (?)	12
Sandy marl with numerous shells that in some portions are finely comminuted and cemented together by calcium carbonate forming a fragmentary rock; contains *Pecten jeffersonius, Venus rileyi, Glycymeris subovata, Delphinula, Arca incile, Ostrea compressirostra, Chama corticosa, Plicatula marginata, Raeta, Pholadomya abrapta, Panopea reflexa, Lucinae, Tellinae, Astarte limulata*	27
Blue sandy clay sometimes stained brown by iron oxide; contains *Tellinae, Spisula delumbis, Yoldia lævis, Pandora crassidens*	5
Sandy gray marl rendered somewhat hard by the calcium carbonate from *Crepidulae* that form the most of the bed; contains *Crepidula spinosa, Arca centenaria, A. incile, Chama corticosa, Ostrea compressirostra, Pecten jeffersonius, Balanus proteus*	13
Soft yellowish-gray sandy marl. Contains *Crepidula*, though not so abundant as in layers above or below	12
Soft yellowish-gray sandy marl grading into a blue clayey arenaceous marl; contains *Crepidula, Callocardia sayana, Turritella alticostata*	12
Total	119

The above section was prepared by G. D. Harris, who made a careful study of the Yorktown cliffs for Dr. Dall. The lowest member is exposed about 2 miles below Yorktown and the highest outcrops near Indian Field Creek.

SECTIONS IN THE JAMES RIVER VALLEY.

Because of the James River being bordered by low land throughout a large part of its lower course outcrops of Tertiary strata appear in few places. However, in certain localities bluffs that are now being cut by the waves of the estuary furnish admirable exposures for study and for the collection of fossils.

South of the James River in Nansemond County there are numerous exposures, especially in the vicinity of Smithfield and Suffolk.

I. *Section one mile east of King's Mill, left bank of James River.*

			Feet
Pleistocene		Yellow loam becoming sandy below	20
Miocene.	Yorktown	Yellow sand	15
		Shell layer in sandy matrix in which *Panopea* predominates	4
		Sandy clay layer, few shells	4½
		Shell layer composed almost entirely of *Chama congregata*	8
		Sandy clay layer containing fewer shells	8
		Layer composed mainly of *Pecten jeffersonius*, very compact	4
		Loose sandy layer containing many small shells and *Pecten clintonius* (exposed)	6
		Total	69½

On Blow's Mill Run, one and one-half miles northwest of Lee Hall, there is a shell layer 10 feet thick exposed about 15 feet above the creek. It contains a great variety of molluscan fossils.

II. *Section right bank of James River at Fergusson's Wharf.*

			Feet
Pleistocene (?)		Concealed by vegetation	20
Miocene.	Yorktown	Fragmental shell mass quite thoroughly indurated, sharply separated from the layer beneath	15
		Blue sandy clay, few fossils	17
		Bed of fossils, in material, similar to above layer; *Chama congregata* especially abundant (exposed to water)	4½
		Total	56½

III. *Section south bank of James River at Morgart's, five miles north of Smithfield.*

			Feet
Pleistocene		Pale yellow sandy loam	2
		Reddish-yellow sandy clay	2-4
Miocene.	Yorktown	Yellowish calcareous highly fossiliferous marl, in some portions material loose, in others firmly indurated by calcareous cement. There is a well-defined horizontal line but no unconformity between this layer and the succeeding	3-5
		Yellowish sandy marl, with numerous casts and some decomposed shells; similar to those in following layer; *Chama*, *Crepidula*, etc. especially abundant	2-3

		Feet
	Yellow weathered sandy marl carrying the same fossils as the layer beneath and gradually passing into it..............	5-8
	Greenish-blue compact sandy marl with some clay, bearing numerous fossils, among them *Ostrea, Turritella, Cardium, Dosinia, Glycymeris, Panopea, Dentalium, Ecphora*	12-15
	Total...............................	37

Indurated shell marl containing an abundant fauna in an excellent state of preservation, is well exposed at and near Smithfield on Pagan Creek and many important collections of fossils have been made at this place.

IV. *Section in marl pit near spring just north of Benn's Church.*

			Feet
Pleistocene		Gray sandy loam........................	2
		Yellow sands with some argillaceous material toward base...........................	3-6
		Unconformity.	
Miocene.	Yorktown	Thick bed of yellow calcareous marl composed of comminuted shells of varying degrees of fineness becoming coarser toward the base of the bed	12
		Total................................	20

V. *Section in marl pit along stream one-quarter mile below Benn's Church.*

			Feet
Miocene.	Yorktown	Yellowish sand	4-6
		Yellowish marl similar to that described in the preceding section	6-8
		Total..............................	14

About ¾ mile west from Benn's Church, near an abandoned mill dam on a small creek similar indurated marl is exposed.

VI. *Section in S. G. Webb's marl pit one-quarter mile north of Chuckatuck on creek about one-quarter mile below dam.*

			Feet
Pleistocene		Yellow sand	3-5
Miocene.	Yorktown	Finely comminuted shells and small forms in matrix of horizontally stratified yellow sand	3
		Alternating layers of shells and sandy marl; the following forms were noted: *Pecten, Dosinia, Glycymeris, Arca, Turritella,* and *Ephora quadricostata*	5+
		Total..............................	13

VII. *Section at Chuckatuck, just below mill dam.*

			Feet
Pleistocene		Gray and yellow sands with numerous small gravel and with occasional indurated layers about	20
		Concealed from view	10
Miocene.	**Yorktown**	Olive green argillaceous marl with some sand, carrying only a few fossils, chiefly *Pecten, Melina, Cardium, Glycymeris,* and *Echinocardium orthonotum*	5
		Total	35

VIII. *Section along roadside near Everet's Creek one-quarter mile east of Everet's Bridge.*

			Feet
Pleistocene		Yellow to gray laminated sand somewhat argillaceous in places and containing an almost continuous band of pebbles at base	5
Miocene.	**Yorktown**	Fine buff to gray sand, blue where unweathered (exposed)	8
		Total	13

Farther down the hill near the bridge shell marl outcrops beneath 3 feet of yellow sand. The shells, for the most part well preserved, are in a matrix of yellow sand. *Turritella* and *Corbula* (?) are especially abundant.

IX. *Section along roadside just south of Exit Post-Office.*

			Feet
Pleistocene		Hard laminated buff sand with some pebbles at base	9
Miocene.	**Yorktown**	Shell marl; fossils, many perfect, contained in a matrix composed of fragmental shells and sand, partially indurated at base. This marl has been dug for fertilizing purposes (exposed)	6
		Gap due to concealment by vegetation	5
	St. Mary's	Just below dam, blue sand containing many small Pelecypods, *Cadulus, Polynices,* etc., (exposed)	6
		Total	26

At the bridge, there is an exposure of this blue sand about 12 feet thick which contains a considerable variety of entire shells.

Much marl is found about Western Branch, Nansemond River, near Reid's Ferry. The shells are in matrix of broken shells much resembling the material at Yorktown.

X. *Section on east side of Nansemond River, about one mile south of Reid's Ferry Post-Office.*

			Feet	Inches
Pleistocene		Surface loam		8
		Laminated drab clay		4
Miocene.	Yorktown	Gray sand	3	
		Yellow loamy sand with impressions of fossils	1	6
		Fragmental shell marl, composed almost entirely of small shell fragments with very few perfect shells, except some exceedingly small species. A few pectens, probably *Pecten eboreus* were seen. The marl has been dug on this farm for use on peanut fields (exposed)	3	
		Total	8½	

XI. *Section in marl pit on Brigg's Creek, about six miles northwest of Suffolk.*

			Feet
Miocene.	Yorktown	Yellow marl made up of broken fragments of shells	6
		Yellow marl, sandy, with numerous well preserved shells such as *Panopea, Urosalpinx, Ostrea, Pecten, Balanus,* etc	3
		Total	9

XII. *Section on Calhoun Creek, about three miles northwest of Suffolk at Calhoun Bridge.*

			Feet
Pleistocene		Yellow sands	6-10
		White sands, fine-grained, cross-bedded	4-6
Miocene.	Yorktown	Blue sandy compact marl highly fossiliferous	12-15
		Total	31

On the south side of the creek, a short distance below the bridge there is a steep bank showing a slightly different section.

XIII. *Section on Calhoun Creek three miles northwest of Suffolk.*

			Feet
Pleistocene		Yellow sands with coarse gravel	10-15
Miocene.	Yorktown	Yellow sandy marl, fossiliferous	10-15
		Blue sandy marl, similar to above, fossiliferous	3-5
		Total	35

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SPECIES.	CALVERT FORMATION.							ST. MARY'S FORMATION.															
	POT. RIVER.	RAP. RIVER.	MAT. RIVER.	JAMES RIVER.			APP. RIVER.	RAPPAHANNOCK RIVER.					CHICK. RIVER.	JAMES RIVER.				BLACKWATER RIVER.		NOTTOWAY RIVER.		MEHERRIN RIVER.	
	Nomini Cliffs.	Carter's Wharf.	Walkerton.	Richmond.	City Point.	Bailey's Creek.	Petersburg.	Bowler's Wharf.	Farnham—2½ mi. south.	Jones Point—¼ mi. below.	Bayport—2½ mi. below.	Urbanna.	Lanexa.	Claremont Wharf.	Sunken Marsh Creek.	Dillard's Wharf.	Cobham Bay.	Zuni.	South Quay—2 mi. below.	Delaware Park.	Sycamore.	Maddelys Bluff.	Branch's Bridge.
MAMMALIA.																							
Delphinodon venustus Leidy				●																			
Ixacanthus conradi (Leidy)																							
Physeter vetus Leidy																							
Orycterocetus quadratidens Leidy																							
Cetotherium leptocentrum Cope																							
Siphonocetus expansus Cope																							
Siphonocetus priscus Leidy																							
Mesocetus siphunculus Cope																							
Rhegnopsis palaeatlanticus (Leidy)					●																		
Thinotherium annulatum Cope																							
Procamelus virginiensis Leidy																							
Proroamerus alleni Berry & Gregory																							
Phoca wymani Leidy				●																			
REPTILIA.																							
Syllomuscris patus Cope																							
Thecachampsa (?) antiqua (Leidy)	●																						
PISCES.																							
Hemipristus serra Agassiz																							
Dasyatus sp. indet				●																			
Protautoga conideus Leidy																							
Pogonias multidentatus Cope																							
ARTHROPODA.																							
Cancroidea	●																	●			●	●	
Balanus cancavus Brown	●					●		●	●	●					●		●	●	●	●	●	●	●
MOLLUSCA. Gastropoda.																							
Tornatina canaliculata Say							●																
Terebra dislocata Say																							
Conus diluvianus Green																							
Drillia limatula Conrad																						●	
Drillia lunata Lea							●																
Oliva litterata Lamarck																							
Olivella mutica Say												●						●			●		
Marginella limatula Conrad																							
Marginella bella Conrad																							
Scaphella obtusa Emmons																					●		
Scaphella mutabilis Conrad												●						●			●		
Fasciolaria rhomboidea Rogers																	●						
Fulgur spiniger Conrad																							
Fulgur pyrum var. incile Conrad																					●		
Fulgur coronatum Conrad								●														/	
Fulgur maximum Conrad																							
Fulgur perversum Linné																							
Ecphora quadricosta Say	●		●			●		●	●			●		●	●	●					●	●	
Ptychosalpinx altilis Conrad																							
Ptychosalpinx laqueatum Conrad							●																
Ptychosalpinx multirugatus Conrad																							
Ilyanassa porcina Say							●																
Ilyanassa isogramma Dall																							
Ilyanassa obsoleta Say																							

TABLE SHOWING DISTRIBUTION OF MIOCENE FAUNA.

SPECIES.	YORKTOWN FORMATION.											MISCELLANEOUS.				
	YORK RIVER.				JAMES RIVER.			NANSEMOND RIVER.								
	Williamsburg—2 mi. north.	Bellefield.	Yorktown.	King's Mill.	Ferguson's Wharf.	Smithfield.	Benn's Church.	Chuckatuck.	Exit.	Reid's Ferry—1½ mi. S. E.	Suffolk.	Westmoreland County.	Stafford County.	Pamunkey River.	James River.	Virginia.
MAMMALIA.																
Delphinodon venustus Leidy																
Ixacanthus conradi (Leidy)																•
Physeter vetus Leidy																•
Orycterocetus quadratidens Leidy																•
Cetotherium leptocentrum Cope															•	
Siphonocetus expansus Cope												•				
Siphonocetus priscus Leidy												•				
Mesocetus siphunculus Cope														•		
Rhegnopsis palaeatanticus (Leidy)			•													
Thinotherium annulatum Cope													•			
Procamelus virginiensis Leidy																•
Prorosmerus alleni Berry & Gregory			•													
Phoca wymani Leidy																
REPTILIA.																
Syllonuscris patus Cope														•		
Thecachampsa (?) antiqua (Leidy)																
PISCES.																
Hemipristus serra Agassiz																•
Dosyatus sp. indet																
Protautoga conideus Leidy																•
Pogonias multidentatus Cope																•
ARTHROPODA.																
Cancroidea			•			•				•	•					
Balanus concavus Brown			•			•	•	•		•	•					
MOLLUSCA. Gastropoda.																
Tornatina canaliculata Say					•			•			•					
Terebra dislocata Say						•					•					
Conus diluvianus Green			•					•								
Drillia limatula Conrad			•			•					•					
Drillia lunata Lea																
Oliva litterata Lamarck		•	•													
Olivella mutica Say			•													
Marginella limatula Conrad			•				•				•					
Marginella bella Conrad			•													
Scaphella obtusa Emmons						•										
Scaphella mutabilis Conrad						•		•			•					
Fasciolaria rhomboidea Rogers																
Fulgur spiniger Conrad											•					
Fulgur pyrum var. incile Conrad			•		•						•					
Fulgur coronatum Conrad											•					
Fulgur maximum Conrad			•			•					•					
Fulgur perversum Linné			•													
Ecphora quadricosta Say		•	•			•		•	•		•					
Ptychosalpinx altilis Conrad			•								•					
Ptychosalpinx laqueatum Conrad			•													
Ptychosalpinx multirugatus Conrad																
Ilyanassa porcina Say		•	•													
Ilyanassa isogramma Dall		•	•													
Ilyanassa obsoleta Say		•														

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granifera Conrad																							
entata Emmons								●										●					
puloides Conrad																							
arrisii Dall																							
brifer Conrad																							
caudata Say																							
strumosa Conrad								●										●			●	●	●
trossulus Conrad																							
ila lepidota Dall																							
ana Dall																							
sta Say																							
ta Conrad																							
selanura C. B. Adams																							
nsi H. C. Lea																					●		
tevensoni Meyer																							
irginianum Meyer																							
is granifera Say					●				●			●		●	●			●			●		●
sculpturatus H. C. Lea							●																●
virginica Conrad												●											
indenta var. bipartita Conrad	●						●	●		●													
terebriformis Dall																							
alticostata Conrad														●				●			●		●
variabilis Conrad			●			●				●		●		●	●	●		●			●		●
lyra Conrad						●	●																
superum Conrad																							
obliquistriabus H. C. Lea							●																
concavus H. C. Lea							●																
m auricula var. imbricatum y																							
m grande Say														●				●			●		
s centralis Conrad							●																
fornicata Say																							
aculeata var. costata Morton												●		●	●	●		●			●		●
plana Say																							
duplicatus Say	●		●				●														●	●	●
heros Say									●	●		●		●		●		●			●		●
na philanthropus Conrad							●					●											
na philanthropus var. basicum							●																
na mitchelli Conrad																							
na ruffini H. C. Lea							●																
na virginicum Conrad																							
na harrisii Dall																							
na distans Conrad																							
na humilis Conrad							●																
a nana H. C. Lea							●																
na pseudadeorbis Dall																							
s catelliformis Rogers							●																
s marylandica Conrad																							
s redimicula Say																						●	●
s alticosta Conrad						●								●									
MOLLUSCA. Scaphopoda.																							
n attenuatum Say						●	●						●	●	●	●		●		●	●	●	●
thallus Conrad							●	●										●			●		●
MOLLUSCA. Pelecypoda.																							
rosima Say								●				●											●
ephris Dall																							●

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Ilyanassa granifera Conrad			●													
Nassa bidentata Emmons																
Nassa harpuloides Conrad			●													
Anachis harrisii Dall			●													
Murex umbrifer Conrad			●													
Eupleura caudata Say			●								●					
Scalaspira strumosa Conrad			●			●					●					
Urosalpinx trossulus Conrad		●	●			●					●					
Coralliophila lepidota Dall											●					
Scala sayana Dall											●					
Scala lineata Say											●					
Triforis melanura C. B Adams							●									
Scila adamsi H. C. Lea			●								●					
Caecum stevensoni Meyer											●					
Caecum virginianum Meyer			●													
Serpulorbis granifera Say		●									●					
Vermetus sculpturatus H. C. Lea						●		●			●					
Vermetus virginica Conrad											●					
Turritella indenta var. bipartila Conrad																
Turritella terebriformis Dall			●													
Turritella alticostata Conrad		●	●			●					●					
Turritella variabilis Conrad			●			●	●	●	●		●					
Fossarus lyra Conrad											●					
Solarium nuperum Conrad			●													
Adeorbis obliquistriabus H. C. Lea																
Adeorbis concavus H. C. Lea																
Crucibulum auricula var. imbricatum Sowerby			●			●	●	●			●					
Crucibulum grande Say											●					
Calyptraea centralis Conrad																
Crepidula fornicata Say		●	●								●					
Crepidula aculeata var. costata Morton		●	●								●					
Crepidula plana Say		●									●					
Polynices duplicatus Say		●	●			●	●				●					
Polynices heros Say		●							●		●					
Calliostoma philanthropus Conrad		●	●								●					
Calliostoma philanthropus var. basicum Dall			●													
Calliostoma mitchelli Conrad			●													
Calliostoma ruffini H. C. Lea			●													
Calliostoma virginicum Conrad			●								●					
Calliostoma harrisii Dall		●	●													
Calliostoma distans Conrad			●													
Calliostoma humilis Conrad																
Teinostoma nana H. C. Lea																
Teinostoma pseudadeorbis Dall			●													
Fissuridea catelliformis Rogers																
Fissuridea marylandica Conrad			●													
Fissuridea redimicula Say			●			●										
Fissuridea alticosta Conrad		●				●										
MOLLUSCA. Scaphopoda.																
Dentalium attenuatum Say		●	●		●	●	●		●	●	●					
Cadulus thallus Conrad			●			●			●		●					
MOLLUSCA. Pelecypoda.																
Nucula proxima Say			●			●		●	●	●	●					
Nucula taphria Dall						●		●		●	●					

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	Nomini Cliffs.	Carter's Wharf.	Walkerton.	Richmond.	City Point.	Bailey's Creek.	Petersburg.	Bowler's Wharf.	Farnham—2½ mi. south.	Jones Point—¼ mi. below.	Bayport—2½ mi. below.	Urbanna.	Lanexa.	Claremont Wharf.	Sunken Marsh Creek.	Dillard's Wharf.	Cobham Bay.	Zuni.	South Quay—2 mi. below.	Delaware Park.	Sycamore.	Maddelys Bluff.	Branch's Bridge.
Leda acuta Conrad																							
Yoldia laevis Say														•				•					
Glycymeris americana de France							•																
Glycymeris subovata Say						•	•					•	•	•	•	•		•					
Glycymeris pectinata Gmelin																							
Arca centenaria Say						•	•		•		•	•	•		•	•		•			•		
Arca limula Conrad																							
Arca incile Say						•	•											•			•		
Arca scalaris Conrad							•																
Arca lienosa Say																							
Arca idonea Conrad												•											
Arca staminea Say																							
Arca improcera Conrad																							
Arca clisca Dall	•																						
Melina maxillata Deshayes	•					•		•	•	•	•	•		•	•	•							
Ostrea compressirostra Say			•		•	•		•				•	•	•	•	•		•			•		•
Ostrea sculpturata Conrad			•				•	•				•	•	•	•	•		•			•	•	•
Pecten jeffersonius Say			•		•	•	•	•				•	•	•	•	•	•	•		•		•	•
Pecten jeffersonius var. edgecombensis Conrad			•			•	•	•				•		•	•	•	•	•			•	•	•
Pecten jeffersonius var. septenarius Say						•	•						•		•	•		•					
Pecten madisonius Say			•		•	•	•				•	•		•	•	•	•				•		
Pecten clintonius Say						•				•			•	•	•		•	•		•	•		•
Pecten virginianus Conrad					•																		
Pecten marylandicus Wagner							•																
Pecten decemnarius Conrad					•																•		
Pecten eboreus Conrad			•		•		•				•		•	•				•			•		•
Plicatula marginata Say							•								•			•				•	
Anomia ruffini Conrad							•																
Anomia simplex d'Orbigny																		•					
Anomia aculeata Gmelin											•	•			•			•					•
Mytilus hamatus Say																							
Modiolus ducatelii Conrad	•						•		•									•	•			•	
Modiolaria virginica Conrad																							
Teredo fistula H. C. Lea						•	•				•	•	•	•					•		•	•	•
Barnea arcuata Conrad																							
Panopea goldfussi Wagner	•					•																	
Panopea reflexa Say	•						•	•		•	•	•		•				•			•		•
Saxicava arctica Linné							•								•			•				•	
Corbula inequalis Say	•		•			•	•	•	•	•	•	•		•	•	•		•			•		•
Corbula cuneata Say																•							
Mya arenaria Linné							•																
Mya producta Conrad																							
Spisula delumbis Conrad																							
Mulinia congesta Conrad	•						•	•	•	•		•	•	•				•	•		•	•	•
Rangia clathrodonta Conrad							•																
Labiosa alta Conrad																							
Ensis directus Conrad							•																•
Ensis ensiformis Conrad														•									
Asaphis centenaria Conrad								•													•		
Tagelus gibbus Spengler								•															
Semele nuculoides Conrad																							
Abra subreflexa Conrad							•																
Cumingia medialis Conrad							•																
Tellina declivis Conrad							•																
Tellina producta Conrad							•																
Macoma conradi Dall																							

TABLE SHOWING DISTRIBUTION OF MIOCENE FAUNA.

SPECIES.	YORKTOWN FORMATION.											MISCELLANEOUS.				
	YORK RIVER.				JAMES RIVER.			NANSEMOND RIVER.								
	Williamsburg—2 mi. north.	Bellefield.	Yorktown.	King's Mill.	Ferguson's Wharf.	Smithfield.	Benn's Church.	Chuckatuck.	Exit.	Reid's Ferry—1½ mi. S. E.	Suffolk.	Westmoreland County.	Stafford County.	Pamunkey River.	James River.	Virginia.
Leda acuta Conrad			●								●					
Yoldia laevis Say		●	●		●	●		●			●					
Glycymeris americana de France			●			●		●			●					
Glycymeris subovata Say		●	●			●	●			●	●					
Glycymeris pectinata Gmelin			●								●					
Arca centenaria Say		●	●		●											
Arca limula Conrad						●	●	●			●					
Arca incile Say		●	●		●	●			●		●					
Arca scalaris Conrad																
Arca lienosa Say			●													
Arca idonea Conrad		●														
Arca staminea Say			●													
Arca improcera Conrad											●					
Arca clisca Dall																
Melina maxillata Deshayes																
Ostrea compressirostra Say		●	●			●	●		●		●					
Ostrea sculpturata Conrad		●	●		●	●	●	●			●					
Pecten jeffersonius Say		●	●	●		●			●		●					
Pecten jeffersonius var. *edgecombensis* Conrad		●	●			●	●	●			●					
Pecten jeffersonius var. *septenarius* Say									●		●					
Pecten madisonius Say		●	●			●					●					
Pecten clintonius Say				●												
Pecten virginianus Conrad																
Pecten marylandicus Wagner																
Pecten decemnarius Conrad		●	●													
Pecten eboreus Conrad		●	●			●		●	●		●					
Plicatula marginata Say		●				●	●	●		●	●					
Anomia ruffini Conrad																
Anomia simplex d'Orbigny			●								●					
Anomia aculeata Gmelin			●													
Mytilus hamatus Say			●													
Modiolus ducatelii Conrad			●			●	●	●	●		●					
Modiolaria virginica Conrad			●													
Teredo fistula H. C. Lea		●	●													
Barnea arcuata Conrad						●					●					
Panopea goldfusii Wagner			●								●					
Panopea reflexa Say		●	●		●	●	●		●		●					
Saxicava arctica Linné							●	●			●					
Corbula inequalis Say		●			●	●	●	●	●	●	●					
Corbula cuneata Say																
Mya arenaria Linné			●													
Mya producta Conrad			●													
Spisula delumbis Conrad			●			●					●					
Mulinia congesta Conrad			●		●	●	●	●	●	●	●					
Rangia clathrodonta Conrad			●													
Labiosa alta Conrad			●													
Ensis directus Conrad											●					
Ensis ensiformis Conrad			●								●					
Asaphis centenaria Conrad			●			●					●					
Tagelus gibbus Spengler			●													
Semele nuculoides Conrad			●													
Abra subreflexa Conrad			●													
Cumingia medialis Conrad			●			●		●			●					
Tellina declivis Conrad			●								●					
Tellina producta Conrad											●					
Macoma conradi Dall			●													

TABLE SHOWING DISTRIBUTION OF MIOCENE FAUNA.

SPECIES.	CALVERT FORMATION.							ST. MARY'S FORMATION.															
	POT. RIVER.	RAP. RIVER.	MAT. RIVER.	JAMES RIVER.			APP. RIVER.	RAPPA-HANNOCK RIVER.					CHICK. RIVER.	JAMES RIVER.			BLACK-WATER RIVER.			NOTTO-WAY RIVER.		MEHERRIN RIVER.	
	Nomini Cliffs.	Carter's Wharf.	Walkerton.	Richmond.	City Point.	Bailey's Creek.	Petersburg.	Bowler's Wharf.	Farnham—2½ mi. south.	Jones Point—¼ mi. below.	Bayport—2½ mi. below.	Urbanna.	Lanexa.	Claremont Wharf.	Sunken Marsh Creek.	Dillard's Wharf.	Cobham Bay.	Zuni.	South Quay—2 mi. below.	Delaware Park.	Sycamore.	Maddelys Bluff.	Branch's Bridge.
virginiana Conrad							•																
harrisii Dall																							
s *carpenteri* Dall							•																
fraterna Say	•				•	•	•					•		•	•	•		•		•		•	
virginianum Conrad																					•		•
laqueatum Conrad							•							•	•								
robustum Solander																							
s *cossmani* Dall							•																
constricta Conrad							•																
protexta Conrad							•																
petropolitana Dall							•																
compressa H. C. Lea																							
yorkensis Dall																							
pelex Dall							•																
iangula Dall							•																
a petropolitana Dall							•																
a sagrinata Dall																							
equata Conrad							•																
a nucleiformis Wagner							•																
ta yorkensis Dall																							
ta acclinis Conrad							•											•					
ta subvexa Conrad																							
ta leana Dall							•																
ta punctulata H. C. Lea							•																
cetabulum Conrad	•		•				•			•		•	•			•		•			•		•
n *metastriatum* Conrad																							•
lista albaria Say			•				•					•											
la sayana Conrad			•				•	•		•													
tilirata Conrad						•				•	•	•											
ena Conrad																							
idacnoides Lamarck					•	•	•											•			•	•	•
cyi Conrad						•	•					•						•				•	
ercenaria Linné												•			•	•							
peciosa Rogers					•									•									
cribrarius Say						•	•							•				•			•	•	
anodonta Say	•				•	•	•			•		•		•	•			•		•			
contractus Say	•					•						•			•			•			•		•
crenulatus Conrad			•			•	•	•		•				•	•			•					•
la quadrisulcata d'Orbigny					•		•						•	•	•	•				•			
orticosa Conrad						•	•							•	•								
ongregata Conrad						•	•					•	•	•	•	•		•			•	•	•
rata Conrad							•																
dia granulata Say			•		•	•	•			•				•	•	•		•		•	•	•	•
s *ovalis* Conrad																							
ites undulatus Say	•		•			•	•			•	•	•	•	•	•	•		•		•	•	•	•
ites lunulatus Conrad			•									•						•			•	•	
ymmetrica Conrad					•		•														•	•	
oheni Conrad							•									•							
ndulata Say	•				•		•				•	•	•	•	•	•	•	•		•	•	•	•
oncentrica var. bella Conrad							•																
crassidens Conrad																		•			•	•	•
onradi Couthouy																							•
transversa H. C. Lea							•																
ria abrupta Conrad							•											•			•		•
LUSCOIDEA. Brachiopoda.																							
s ***lugubris*** **Conrad**	•		•		•	•			•		•	•				•							•

TABLE SHOWING DISTRIBUTION OF MIOCENE FAUNA.

SPECIES.	YORKTOWN FORMATION.											MISCELLANEOUS.				
	YORK RIVER.			JAMES RIVER.				NANSEMOND RIVER.								
	Williamsburg—2 mi. north.	Bellefield.	Yorktown.	King's Mill.	Ferguson's Wharf.	Smithfield.	Benn's Church.	Chuckatuck.	Exit.	Reid's Ferry—1½ mi. S. E.	Suffolk.	Westmoreland County.	Stafford County.	Pamunkey River.	James River.	Virginia.
Macoma virginiana Conrad																
Petricola harrisii Dall		•	•													
Cooperella carpenteri Dall																
Isocardia fraterna Say		•	•													
Cardium virginianum Conrad											•					
Cardium laqueatum Conrad											•					
Cardium robustum Solander			•													
Solecardia cossmani Dall																
Sportella constricta Conrad																
Sportella protexta Conrad																
Sportella petropolitana Dall																
Sportella compressa H. C. Lea			•													
Sportella yorkensis Dall			•													
Sportella pelex Dall																
Bornia triangula Dall			•													
Montacuta petropolitana Dall																
Montacuta sagrinata Dall			•													
Aligena aequata Conrad										•	•					
Diplodonta nucleiformis Wagner			•													
Diplodonta yorkensis Dall			•													
Diplodonta acclinis Conrad			•								•					
Diplodonta subvexa Conrad						•					•					
Diplodonta leana Dall																
Diplodonta punctulata H. C. Lea																
Dosinia acetabulum Conrad		•	•			•			•		•					
Gafrarium metastriatum Conrad			•								•					
Macrocallista albaria Say			•													
Callocardia sayana Conrad		•	•			•		•			•					
Chione latilirata Conrad			•								•					
Venus plena Conrad		•	•													
Venus tridacnoides Lamarck		•	•		•											
Venus rileyi Conrad		•	•		•	•	•				•					
Venus mercenaria Linné																
Codakia speciosa Rogers			•													
Phacoides cribrarius Say			•		•	•										
Phacoides anodonta Say		•	•													
Phacoides contractus Say											•					
Phacoides crenulatus Conrad			•		•		•	•		•	•					
Divaricella quadrisulcata d'Orbigny			•								•					
Chama corticosa Conrad		•	•			•										
Chama congregata Conrad		•	•		•	•	•	•								
Cardita arata Conrad		•	•			•	•	•		•	•					
Venericardia granulata Say		•	•	•			•	•			•					
Erycinella ovalis Conrad			•													
Crassitellites undulatus Say		•	•		•		•	•	•	•	•					
Crassitellites lunulatus Conrad			•			•	•	•		•	•					
Astarte symmetrica Conrad																
Astarte coheni Conrad																
Astarte undulata Say				•	•											
Astarte concentrica var. bella Conrad			•			•	•	•		•	•					
Pandora crassidens Conrad			•			•					•					
Thracia conradi Couthouy			•			•										
Thracia transversa H. C. Lea			•													
Margaritaria abrupta Conrad			•			•					•					
MOLLUSCOIDEA. **Brachiopoda.**																
Discinisca lugubris Conrad		•	•													

On Calhoun Creek about 1½ miles northwest of Suffolk Waterworks there is an exposure of marl 12 to 14 feet thick containing shells in a sand matrix.

About 1½ miles north of Suffolk the new Tidewater Railroad has made a cut 8 to 12 feet in depth in which there is an excellent exposure of Miocene fossils preserved in a matrix of blue sand. In this vicinity the greatest outcrop of the fossil bed is about 6 feet. It may extend below the level of the cut. Above it there is Pleistocene buff to gray sand with a rather persistent line of coarse cobbles immediately at the base and resting on the shell marl. Many species of fossils have been obtained at this locality.

XIV. *Section at Suffolk Waterworks, about one mile west from Suffolk on Smith Creek.*

			Feet
Pleistocene		**Yellow sand carrying considerable gravel**	**4-5**
Miocene.	**Yorktown**	**Yellow sandy marl with numerous fairly well preserved shells and large quantities of shell fragments**	**6-8**
		Total	**13**

Below dam of pond which supplies city of Suffolk with water there is an exposure of blue sandy earth containing many well preserved fossils.

Many Yorktown fossils in excellent condition were collected along ditches in edge of Dismal Swamp about 1 mile east of Suffolk from matrix of blue sand about 3 feet below the surface.

PLIOCENE. (?)

The Virginia deposits tentatively referred to the Pliocene belong to the Lafayette formation. They are developed in the extreme western portion of the Coastal Plain near the Piedmont border and consist of gravels and loams which accumulated in shallow marine or estuarine waters in proximity to the shore. Certain marine fossiliferous beds exposed along the Dismal Swamp canals in the extremely southeastern part of the State were formerly thought to represent a marine facies of the Pliocene and have been so described[a] but more recent investigations have shown them to be of later date.

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[a] Proc. Acad. Nat. Sci. Phila. for 1898, pp. 414-424, 1899. Norfolk Folio, U. S. Geol. Survey No. 80, p. 3, 1902.

The Lafayette Formation.

Name.—The name Lafayette was proposed by Hilgard[a] in 1891 from Lafayette County, Mississippi, to replace the terms "Orange Sand" hitherto employed in Tennessee and Mississippi and for "Appomattox" which was used in Virginia, District of Columbia, and Maryland, for these deposits.

Since Berry[b] has shown that the so-called Lafayette of the type section in Lafayette County, Miss., is of Eocene age, the question of the proper nomenclature for these surficial deposits of the middle Atlantic slope will have to be reconsidered.

Lithologic character.—The formation is composed of gravels, sands, and loams, usually unconsolidated, although locally cemented by iron oxide. The beds in most cases show approximately horizontal stratification although occasionally stratification lines are not noticeable; at other times the deposits show marked cross-bedding. The materials of the various beds were imperfectly sorted by the waves of the Lafayette sea, so that the gravels, sands, and loam are frequently found intermingled. There is a rough bipartite division in the deposit, as a whole, whereby the gravel occurs in greater abundance at the base and the sand and loam at the top of the formation. In certain places, however, irregular lenses of loam may occur in the lower gravelly portion and beds of gravel and sand in the upper loamy portion.

The gravels of the Lafayette furnish the most characteristic feature of the formation, as they constitute the greater portion of the deposits, and are seen in almost every exposure of the formation. They are of various sizes, ranging from coarse sand to cobbles several inches in diameter generally imbedded in a matrix of sand or sandy loam. Near the crystalline rocks the gravels are commonly coated with a thin layer of ferruginous material which increases their value for road-making purposes. The gravels are almost invariably well-rounded. They are mainly of quartz although pebbles of gabbro and other igneous rocks, usually much decomposed, occur. Pebbles of fine-grained and quartzitic sandstones from the Appalachian region with impressions of Paleozoic fossils are found in places and also pebbles of Newark sandstone. A large part of the gravel is doubtless reworked Potomac material, derived from nearby regions. The heterogeneous character of the pebbles thus furnishes evidence of the varied sources from which the gravels have been obtained.

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[a] Amer. Geol. vol. iii, pp. 129-131.

[b] Jour. of Geol., vol. xix, pp. 249-256, 1911.

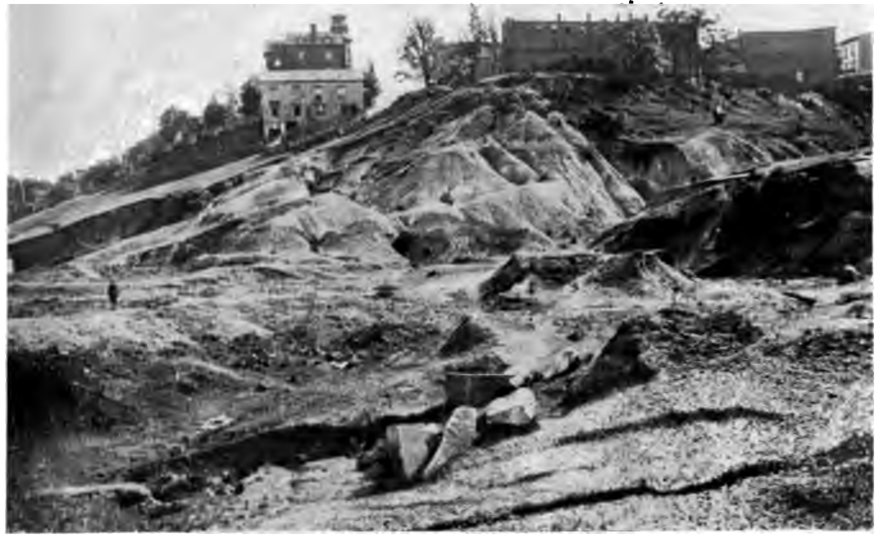

Fig. 1.—Locality at Richmond showing Lafayette formation overlying Calvert formation.

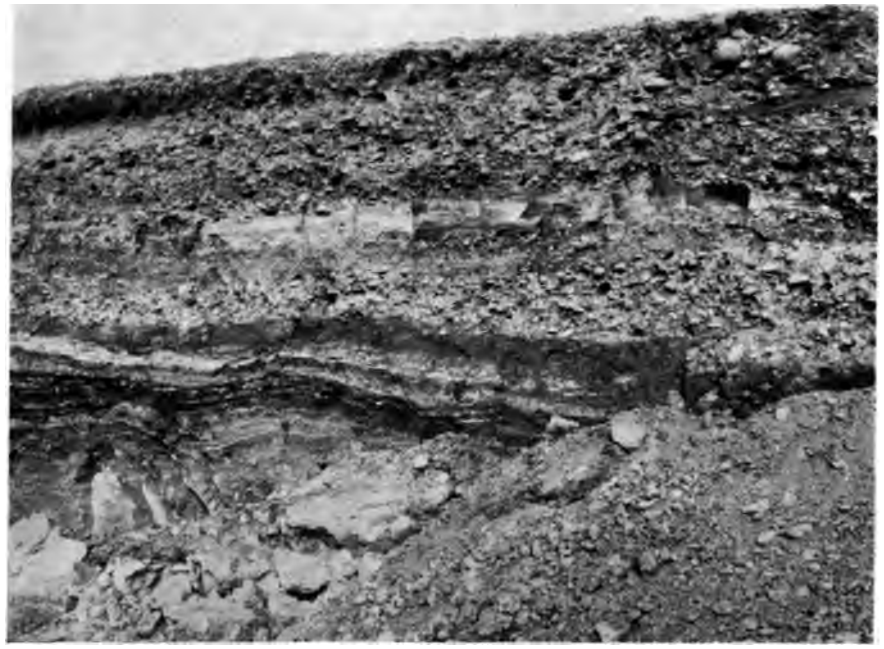

Fig. 2.—Pit at Washington, D. C. Showing Lafayette formation overlying Calvert formation.

LAFAYETTE FORMATION OVERLYING CALVERT FORMATION.

Sand forms a rather unimportant part of the Lafayette deposit. Such as is present was doubtless mainly derived from the Potomac beds. Lenses of sand are frequently found in the gravel deposits, but rarely does the sand form beds of any considerable thickness or areal extent. It usually serves as the matrix for the gravels, or else is intimately mixed with the loam.

At points where the formation has suffered little erosion the uppermost beds consist of loam, varying in thickness from a few inches to 10 feet or more. Observations made in many places seem to indicate that this loam is much thicker in the vicinity of Richmond than elsewhere in the State, and there consists of a reddish-brown clayey loam which has been utilized in the manufacture of brick at several points near the city. When wet the loam not infrequently shows a very pronounced mottling of drab and brick-red. Although the loam cap is relatively free from bands of gravels, they are not entirely absent. Single pebbles are not uncommon in the loam, and at times there are well-defined beds of gravel and sand. Some of these pebbles are well rounded but angular quartz fragments are also present, particularly in proximity to the crystalline rocks. There the Lafayette deposits may bear such a striking resemblance to the residual materials of the metamorphic rocks that the presence of occasional rounded water-worn pebbles mixed with the angular fragments is the only clue to the real character of the beds. In such cases the bulk of the material does undoubtedly consist of such residuum which has only been transported a short distance, although, in this process, water-worn gravels which have been transported greater distances have become mixed in small amounts with the residual clay. At the brick yard near the reservoir west of Richmond there is such a clay deposit about 18 feet in thickness, the upper part of which is deep red in color, the lower mottled and white, which could scarcely be distinguished from the residual material, were it not for the presence of a few rounded pebbles distributed through the deposit.

The variable character of the Lafayette materials renders detailed sections of little value, but the following section exposed in northwest Richmond along the Seaboard Air Line Railroad, near Beacon's Quarter Branch, furnishes a good idea of the materials.

Section exposed in Northwest Richmond near Beacon's Quarter Branch.

	Feet
Red clay loam containing many small rounded pebbles irregularly distributed throughout the bed	9
Poorly sorted coarse and fine gravel in matrix of coarse sand, red clay, or arkose (exposed)	18
Total	27

Strike, dip and thickness.—The strike of the Lafayette formation is in a north and south direction, while there is a slight dip to the east, a dip which seems to be due partly to the general slope of the bottom upon which the strata were deposited and partly to a slight subsequent tilting. The thickness is variable, owing largely to the irregularities of the underlying beds, the greatest thickness being in the vicinity of the larger streams of the period which brought down the materials from the westward and deposited them in the Lafayette sea. The waves and currents spread this débris some distance from the stream mouths along the coast thus forming a continuous deposit over the entire submerged area. The coarser materials were mainly dropped in the vicinity of the streams. The thickness generally does not exceed 30 or 35 feet although in some places it is considerably in excess of 50 feet.

Stratigraphic relations.—A very marked unconformity separates the Lafayette from all the underlying formations. In one place or another within the Coastal Plain province it overlies almost every older formation represented within the region, and thin remnants are found in many places, resting on the crystalline rocks of the Piedmont Plateau. In Virginia, the Lafayette is chiefly found in contact with the Potomac, Eocene, and Miocene formations and so far as known is a surface deposit, although locally it, in all probability, dips beneath deposits of Pleistocene age.

Paleontologic character.—Fossils are practically lacking in the Lafayette deposits of the Atlantic Coastal Plain, only a few fragments of molluscan shells which are very imperfect and seem to be re-deposited Miocene fossils have been reported from Virginia deposits of doubtful Lafayette age. Sandstone and chert pebbles containing Paleozoic fossils are found in the formation at many places throughout the district but are of importance only in showing the source of the materials. In regions to the south of Virginia some fossil plants and animals of Lafayette age have been reported, but very little is known concerning them.

Areal distribution.—The Lafayette formation covers the divides along the western part of the Coastal Plain and occurs as outliers resting upon the crystalline rocks of the Piedmont Plateau to the southwest of Washington, west of Richmond, and in many other places. Its distribution is co-extensive with the distribution of the Lafayette terrace described in the chapter on physiography. In its wider distribution the Lafayette formation has been traced as a nearly continuous mantle over the older members of the Coastal Plain deposits all the way from the Mississippi valley, parallel with the Coastal border, to Virginia and southern Maryland, north of which the deposits become less extensive and are represented in northern Maryland, Delaware, and Pennsylvania by only a few small remnants.

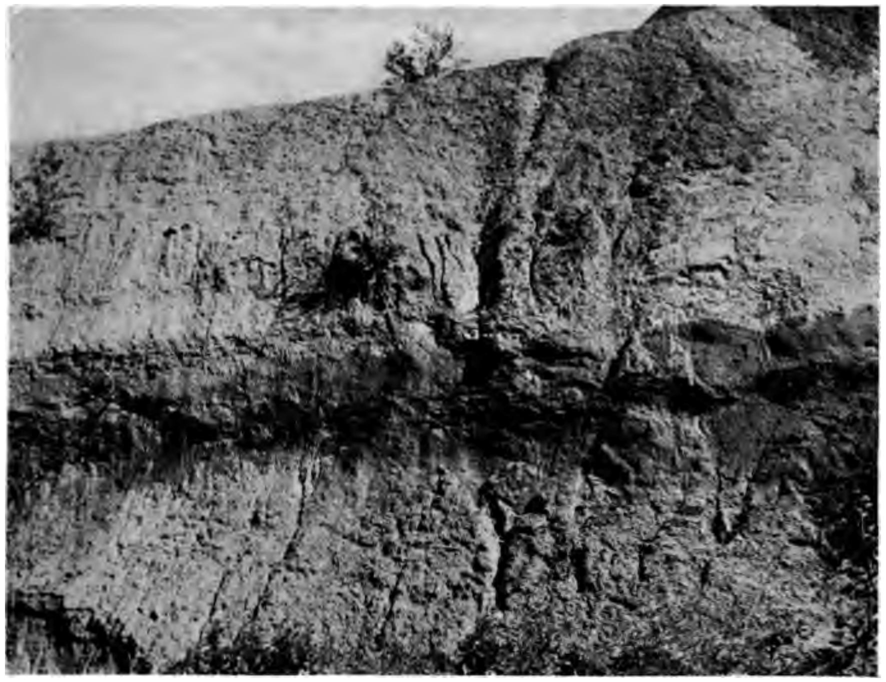

Fig. 1.—Excavation at Richmond. Showing Lafayette formation overlying Aquia formation.

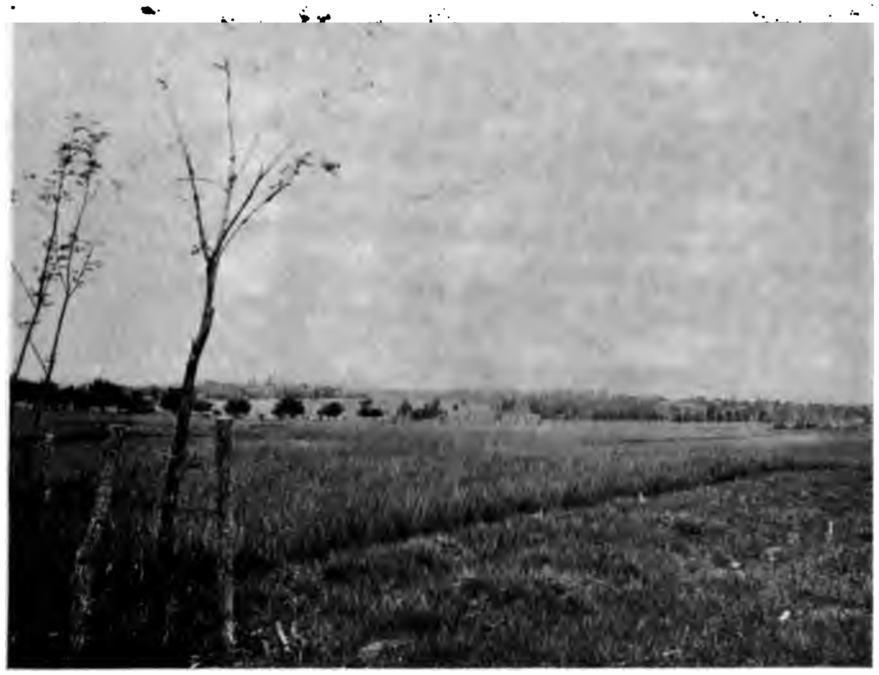

Fig. 2.—Surface of country at Malvern Hill. Showing Lafayette surface.

LAFAYETTE FORMATION AND SURFACE.

QUATERNARY.

The Quaternary deposits of the Virginia Coastal Plain belong to the Pleistocene and Recent epochs, both well represented by surface deposits which although thin have a very wide areal distribution. Together they conceal almost all of the older formations except along the valleys where stream cutting has exposed them..

PLEISTOCENE.

COLUMBIA GROUP.

The Pleistocene formations of the Atlantic Coastal Plain are united under the name of Columbia group. The name Columbia was first employed as a formation name, when it was believed that the Pleistocene deposits of the region represented a single stratigraphic unit. Later a twofold classification of the Pleistocene was recognized and the formations were designated as the Earlier and Later Columbia. Further investigation revealed the fact that the Later Columbia deposits should also be divided. The formations have been given the names of Sunderland, which is the equivalent of the Earlier Columbia, and Wicomico and Talbot which constitute the Later Columbia.

The Columbia deposits consist in general of gravel, sand, and loam. On purely lithologic grounds it is impossible to separate the three formations. In each case the deposits have been derived mainly from the older formations which occur in the immediate vicinity with which is mixed more or less foreign material brought in by streams from the Piedmont Plateau or from the Appalachian region beyond. The deposits of each of these formations are extremely variable and change character according to the underlying formations. Thus materials belonging to the same formation in adjacent regions may differ far more lithologically than the materials of two different formations, lying in proximity to each other. At times the older Pleistocene deposits are somewhat more indurated and the pebbles more decomposed than in the case of the younger formations, but these differences have small value as criteria for the discrimination of the formations, since loose and indurated and fresh decomposed materials occur in each of the formations.

The fossils found in the Pleistocene deposits are far too meager to be of much service in differentiating the formations. It is the exceptional and not the normal development of the formations which has rendered the preservation of fossils possible. They consist principally of plants preserved in fossil bogs, although in a few widely separated places deposits containing great numbers of marine and estuarine molluscs have been found.

Physiographically the Columbia group is readily seen to consist of more than a single unit. Each formation occupies a well-defined wave-built terrace or plain separated by a wave-cut escarpment from the terraces above and below it. At the base of each of the escarpments the underlying Cretaceous and Tertiary formations are at times exposed. The highest terrace is composed of the oldest deposits, the Sunderland, the next lower by the younger, the Wicomico, while the lowest terrace is covered with the youngest or Talbot materials.

In most places where good sections of Pleistocene beds are exposed the materials were evidently deposited continuously from base to summit. In some places, however, certain layers or beds are sharply separated from underlying or overlying beds by uneven lines. These beds usually disappear in short distances and seem to have no relation to similar lines in adjacent regions, showing clearly that they are only local phenomena within the same formation, produced by the contemporaneous erosion of shifting shallow water currents. Since the Pleistocene formations occupy a position so nearly horizontal it should be possible even with the relatively few sections exposed to connect these lines if they represent subaerial erosional unconformities. In the absence of any definite evidence therefore showing these lines to be stratigraphic breaks between two different formations, they have been disregarded. Yet it is not improbable that in some places the waves of the advancing sea may not have entirely removed the beds of the preceding period of deposition over the area covered by its transgression. Especially would deposits laid down in depressions be likely to persist as isolated remnants which later would be covered by the next mantle of Pleistocene materials. If this is the case, each formation from the Lafayette to the Wicomico is probably represented by fragmentary deposits beneath the later Pleistocene formations. Thus in certain sections the lower portions may represent an earlier period of deposition than the upper.

In those regions where older materials are not exposed in the base of the escarpment, each Pleistocene formation near its inner margin probably rests upon the attenuated edges of the next younger formation. Since lithologic differences furnish insufficient criteria for separation of these late deposits and the sections do not afford the data necessary to distinguish between local inter-formational unconformities and widespread stratigraphic unconformities resulting from an erosion interval, the whole mantle of Pleistocene materials occurring at any one level is referred to the same formation. The Sunderland is described as including all the surface deposits from the base of the Lafayette-Sunderland escarpment to the base of the Sunderland-Wicomico escarpment. The few deposits of Lafayette materials which may possibly underlie the Sunderland are thus disregarded because unrecognizable. Similarly the Wicomico is described as including all the surface deposits extending from the base of the Sunderland-Wicomico escarpment to the base of the Wicomico-Talbot escarpment. In the same way it is possible that remnants of the Lafayette and Sunderland formations may occur beneath the Wicomico. The Talbot is described as including all of the surface deposits extending from the base of the Wicomico-Talbot terrace to the base of the Talbot-Recent escarpment. It may also occasionally conceal beneath its mantle of surface materials some remnants of the earlier Pleistocene formations.

The Sunderland Formation.

Name.—The formation has been so named from its typical development on the peninsula of Calvert County, Maryland, near the little village of Sunderland.

Lithologic character.—The materials which compose the Sunderland formation consist of clay, sand, gravel and ice-borne boulders. These rarely lie in well-defined beds but grade into each other vertically and horizontally. The sands are frequently cross-bedded, while the clays are often developed as lenses. The coarser materials commonly occupy the lower portions of the formation with the finer sand and loam above, but the transition from the coarser to the finer strata is seldom abrupt. Lenses of gravel occur in the upper loam, while beds and lenses of loam are interstratified with the coarse sand and gravel below. The erratic ice-borne boulders are scattered throughout the formation and may occur in the gravel beds near the base of the formation or in the loam above. As in the case of the Lafayette formation, the coarse materials are much more abundant in the vicinity of the larger streams of Sunderland time which transported the gravels from the Piedmond Plateau and the Appalachian region beyond to their present resting place.

That the Potomac River was in existence at that time and emptied its waters into the ocean or a wide estuary in the vicinity of Washington is proved by the coarse sediments that are found in that vicinity. The waves along the shore distributed much of the material brought down by the streams but were not strong enough to transport the coarse material to any great distance from the stream mouths.

Much of the finer materials constituting the Sunderland deposits were undoubtedly derived from the immediately underlying Cretaceous and Tertiary beds, although no inconsiderable amount of both fine and coarse débris unquestionably came from the Lafayette deposits which were largely destroyed over the region of Sunderland deposition by the waves of the advancing sea.

The following section exposed near the Chickahominy River north of Richmond illustrates the character of the Sunderland formation.

Section in Chickahominy River Valley north of Richmond.

			Feet
Pleistocene		Brownish-yellow and mottled clay loam	4
		Band of clay containing few small pebbles	1
		Brown ferruginous sand mixed with clay	5
		Gravel layer with pebbles 1 to 3 inches in diameter	1¼
Miocene.	Calvert	Compact drab clay containing many fossil casts (exposed)	10
		Total	21¼

Strike, dip, and thickness.—The beds of the Sunderland are practically horizontal, the gentle dip to the southeast being very slight and due for the most part to the gentle slope of the Sunderland sea floor in that direction, although a slight tilting since Sunderland time may have increased the southeasterly inclination of the beds. The thickness of the formation is occasionally 40 to 50 feet, but usually considerably less, the thickest portions of the formation representing the filling of depressions in the pre-Pleistocene floor.

Stratigraphic relations.—The Sunderland formation throughout the Coastal Plain overlies unconformably the various formations belonging to the Potomac, Eocene, and Miocene groups. It is not improbable that the edges of the Lafayette formation extend out beneath part of the Sunderland deposits although this cannot be determined in the absence of any definite line denoting a stratigraphic break and because of the similarity of the two formations. It is probably overlain unconformably in certain places by the Wicomico and Talbot formations as already explained.

Paleontologic character.—No fossils have been found in the Sunderland deposits of Virginia except the pebbles with Paleozoic remains derived from the Appalachian region. In Maryland some clay beds containing plant remains are found in the deposits but they are neither numerous nor

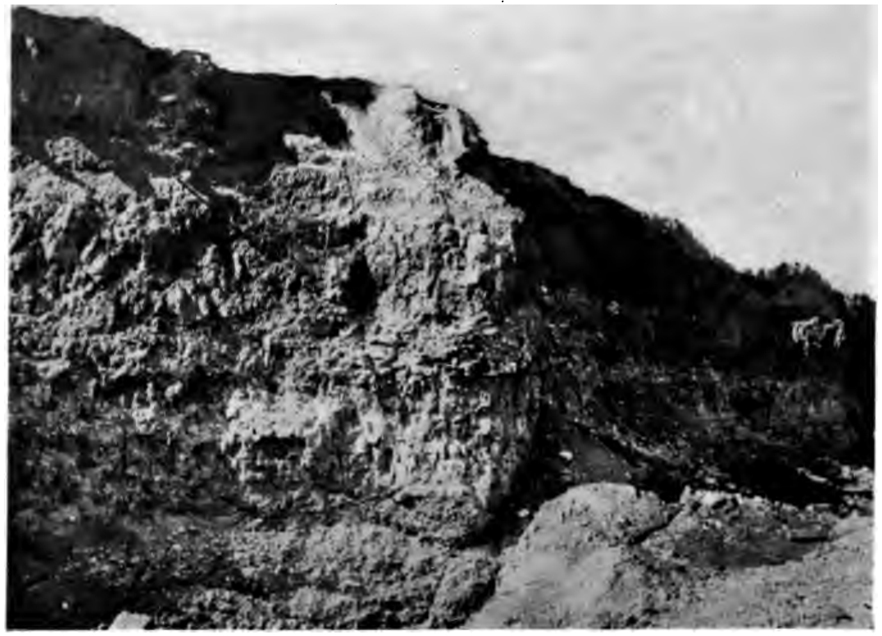

Fig. 1.—Excavation at Richmond. Showing gravels and loams of the Sunderland formation.

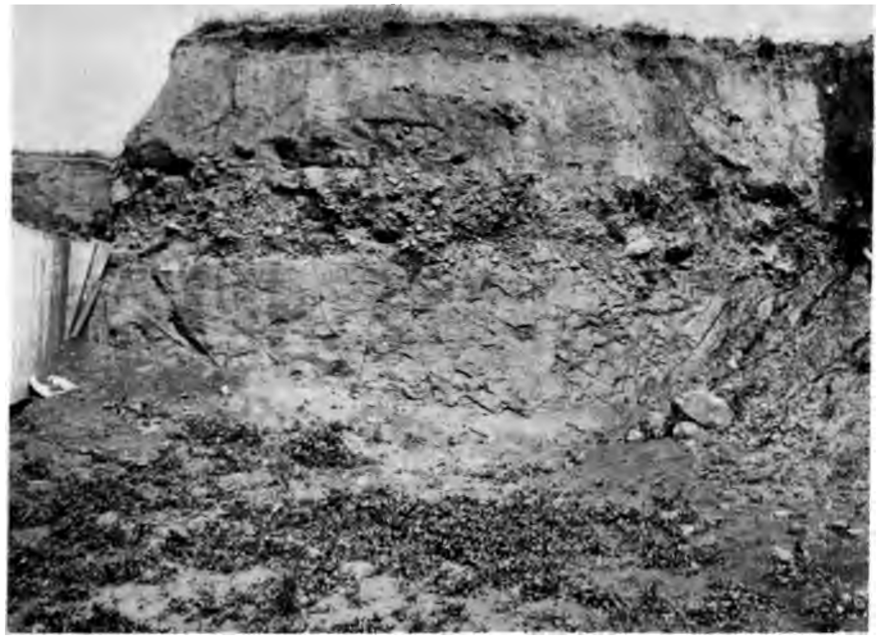

Fig. 2.—Excavation at Washington, D. C. Showing the Wicomico formation overlying crystalline rocks.

SUNDERLAND AND WICOMICO FORMATIONS.

distinctive. A more careful search of the Sunderland deposits of Virginia will undoubtedly show similar plant remains, for plant life must have existed in the region of deposition as shown by the dark color of some of the clays which is evidently due to carbonaceous matter in a finely disseminated condition.

Areal distribution.—The distribution of the formation is co-extensive with that of the Sunderland terrace already described as forming the upland divides between the major streams in a belt extending from Westmoreland to Southhampton counties. The formation except over the broader divides is greatly dissected, and the normal plain-like character of the Sunderland surface is frequently wanting. Since its deposition it has suffered much more erosion, than either of the two younger formations, but enough of the surface still remains to establish its identity over an extensive area.

The Wicomico Formation.

Name.—The Wicomico formation receives its name from the Wicomico River which enters the Potomac from the Maryland side between Charles and St. Mary's counties.

Lithologic character.— The materials which constitute the Wicomico formation are similar to those found in the Sunderland, and in fact, many of them have doubtless been derived from that formation. As stated on a previous page, it would be impossible to distinguish between the Pleistocene formations on the basis of lithologic differences. The criterion of position is the only accurate method of discrimination. The deposits consist of clay, sand, gravel, and ice-borne boulders which grade into each other both vertically and horizontally. It is noticeable, however, as in the case of the Sunderland, that there is a preponderance of the coarser materials at the base of the formation, while the finer materials are largely developed toward the top. Decayed pebbles of the Piedmont crystalline rocks and Paleozoic fossil-bearing pebbles from the Appalachian region are frequently found in the gravel beds or are irregularly distributed in the sands and clays.

In the Potomac valley near Washington, boulders carrying glacial striae have been found in the Wicomico formation. The great size of the boulders and their occurrence with much finer materials furnish the evidence of their transportation by floating ice. The amount of loam present in the Wicomico is exceedingly variable. Wherever the loam cap is well-developed the roads are very firm and the land is suitable for the production of grass and grain, but in those regions where the loam is present in small quantities, or absent altogether, the roads are apt to be very sandy and the soil poor. Much of the Wicomico loam is suitable for the manufacture of common brick and has been used for such purposes in many places throughout Virginia. The following section of Wicomico materials is exposed in the pit of the West End Brick Company, one-half mile west of Suffolk.

Section exposed in clay pit, one-half mile west of Suffolk.

	Feet
Yellow-clay loam grading downward into a very compact and stiff light-colored drab clay containing numerous iron stains	10
Black clay containing very fine quartz grains	1½
Compact drab clay (exposed)	1
Total	12½

Strike, dip, and thickness.—The Wicomico formation occupies a nearly horizontal position, dipping slightly toward the larger streams and Chesapeake Bay. The inclination of the beds is due primarily to the inclined slope on which the deposits were formed, although the eastward dip has probably been somewhat accentuated by a slight eastward tilting subsequent to the deposition of the strata. The uneven floor upon which the materials were accumulated evidently accounts for the variation in thickness of the formation although deposition was in most cases greater in the vicinity of the stream mouths. The formation is seldom more than 40 feet in thickness and is usually much less.

Stratigraphic relations.—The Wicomico overlies unconformably the various formations of Cretaceous or Tertiary age. It is frequently in contact with the Sunderland on the one hand and with the Talbot on the other and at the Wicomico-Sunderland escarpment it is not improbable that in places the Sunderland extends below this scarp line and may extend out beneath the edge of the Wicomico formation. It is also possible, as above stated, that the Wicomico in certain places extends out beneath the Talbot formation at the base of the Wicomico-Talbot scarp.

Paleontologic character.—The character of the Wicomico deposits is such as to indicate unfavorable conditions for the preservation of fossils. No fossiliferous beds have been reported from Virginia, but in Maryland plant beds within the Wicomico formation have been observed in several different places. Sometimes these plant beds form a layer of impure peat, at other times the plant remains are found as impressions only in beds of drab clay. The plant remains are mainly grasses and stems. Among the plant remains a few wing covers of beetles have also been found.

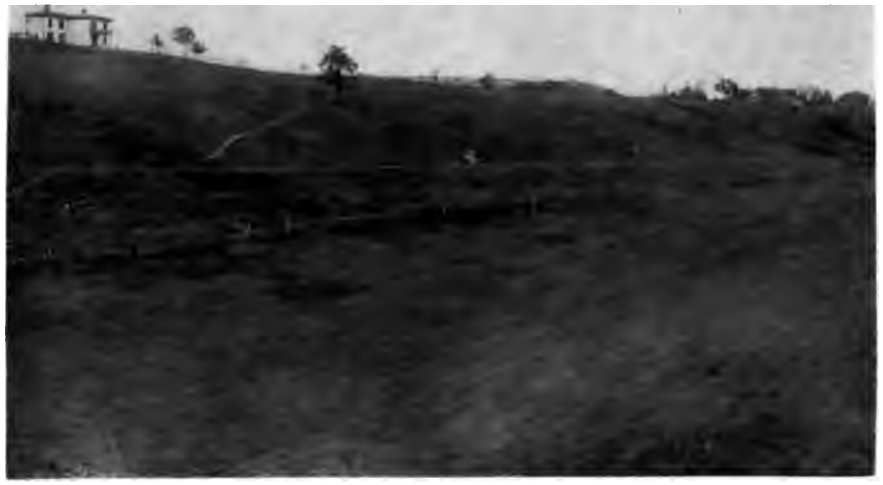

Fig. 1.—Wicomico-Talbot escarpment at Fredericksburg.

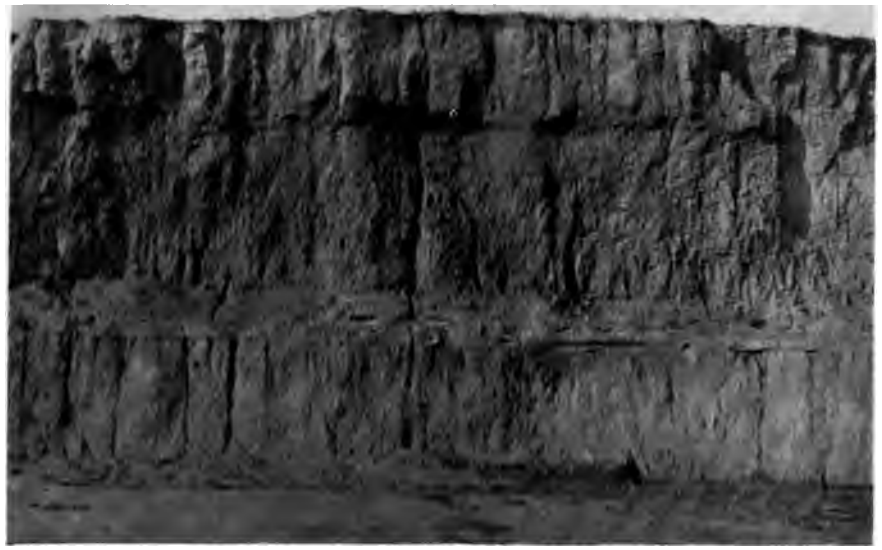

Fig. 2.—Talbot clays at Brick Haven.

WICOMICO-TALBOT ESCARPMENT AND TALBOT CLAYS.

Areal distribution.—The distribution of the Wicomico strata is the same as that of the terrace of the same name described in the chapter on physiography. It occupies the uplands between the lower courses of the large estuaries and frequently extends up the larger valleys as a narrow or wide discontinuous terrace to the head of tide-water. Along the peninsulas between the James and Potomac rivers the Wicomico forms a band of variable width occupying a position between the Sunderland covered divides and the Talbot terrace that skirts the rivers and Chesapeake Bay. South of the James River, however, the Wicomico occupies a wide area extending from the James River to the North Carolina line and beyond, and from the western margin of the Dismal Swamp to the vicinity of the Blackwater River. In this broad area the Sunderland is absent and the Wicomico formation covers the stream divides which are broad and flat, while the streams have cut shallow valleys below the general level of the surrounding country. An escarpment separates the formation from the Sunderland formation above and another divides it from the lower-lying Talbot formation. The escarpment between the Wicomico and Talbot is very well marked in many places, being especially well-developed along the western margin of the Dismal Swamp and from there continues almost due north to the James River. It is also plainly shown between the James and York rivers between Newport News and Yorktown, and north of Gloucester Point on the peninsula between the York and Rappahannock rivers. The Wicomico surface is very conspicuous along the upper estuarine portion of the Rappahannock River where it is frequently over a mile in width and forms a pronounced terrace below the Sunderland deposits that cover the divides.

The Talbot Formation.

Name.—The Talbot formation has received its name from Talbot County, Maryland, where the deposits of this age form a broad terrace bordering the numerous estuaries.

Lithologic character.—The materials which compose the Talbot formation consist of clay loam, peat, sand, gravel, and ice-borne boulders. As in the Sunderland and Wicomico formations, these materials grade into each other both vertically and horizontally and the same bipartite division with the coarser materials beneath and the finer ones above is present in the Talbot as in the others. There is on the whole much less decayed material in the Talbot than in the two preceding formations and this gives to the formation a much younger appearance although this difference cannot be always relied on. The Talbot also contains less coarse material than do the other two Pleistocene formations. Sand and loam predominate, although some gravel and boulders occur either in bands or irregularly distributed through the finer materials in almost every region where the formation is developed. The Potomac River evidently brought down a great many glacial boulders during the Talbot submergence, and these carried by floating ice were dropped in the various deposits then forming. A number of these have been found in the region of Washington which show their glacial character by the planation they have suffered and the glacial striae they bear. Some of them may have come from the earlier Pleistocene deposits, and have been re-deposited, but it is improbable that many have had such an origin.

The materials of the Talbot were derived in part from the destruction of the older Pleistocene strata and the underlying Cretaceous and Tertiary formations by the waves of the Talbot sea and its estuaries, yet, as in the preceding periods, the streams doubtless brought down much additional material from the Piedmont Plateau and the Appalachian region beyond. The Talbot materials therefore like those of the preceding formations are exceedingly heterogeneous in character.

A type of deposit not thus far recognized in the older Pleistocene formations in Virginia, although occurring in them elsewhere, is peat which is developed extensively along the Rappahannock River. About a mile above Tappahannock the river has cut into an old Talbot swamp deposit containing peat and many upright cypress stumps which are still in an excellent state of preservation.

Section exposed in Rappahannock River bluff, one mile above Tappahannock.

	Feet
Yellowish-brown loam grading downward into sand	12
White to ash-colored fine sand	4
Band of fine gravel with a few pebbles an inch in diameter	3½
Drab clay containing pieces of lignite and plant impressions with many cypress knees and stumps derived from the bed below	0-4
Compact brown to black peat containing numerous upright cypress knees and stumps in place, some of the stumps reaching 4 feet in height and 5 feet in diameter (exposed)	1-4½
Total	28

The river in cutting into the deposit has removed in places the clay and peat, leaving many knees and stumps exposed. The line of separation

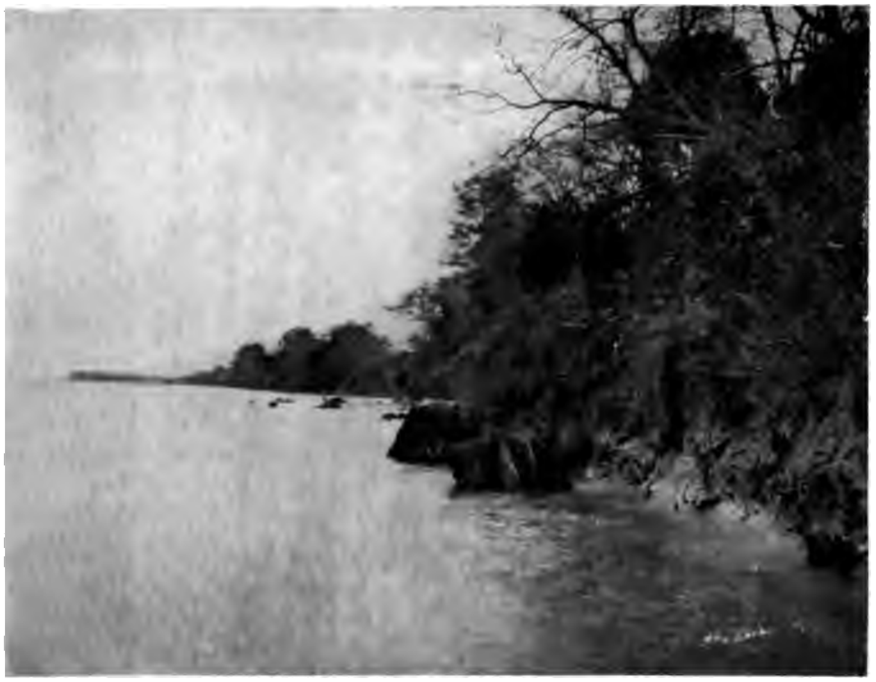

Fig. 1.—Low bluff ½ mile below Bayport Wharf, Rappahannock River. Showing cypress stumps and knees in peat bed of the Talbot formation.

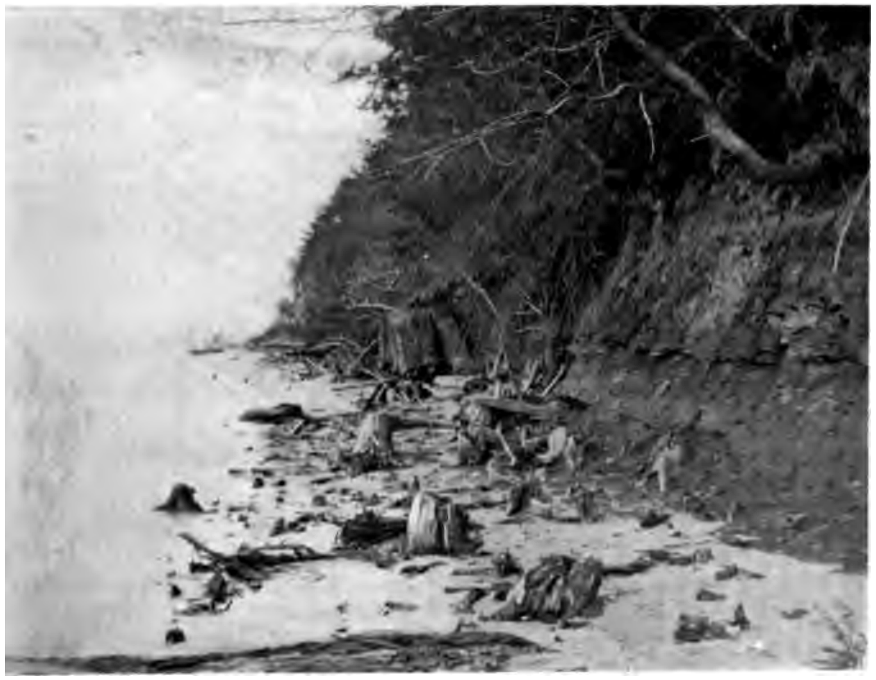

Fig. 2.—Low bluff 1½ miles above Tappahannock, Rappahannock River. Showing cypress stumps and knees in peat bed of the Talbot formation.

CYPRESS STUMPS AND KNEES IN PEAT BED OF TALBOT FORMATION.

between the drab clay and the gravel band above is a very sharp one and represents a decided change in deposition. It is believed that the swamp accumulation was formed in the lower course of a tributary stream of the Rappahannock which had been dammed by the formation of a bar across its mouth. Many examples of such ponded streams are now to be observed all along the tidal estuaries. Partially separated from the waters of the Rappahannock, swamp vegetation, probably similar to that now growing in the Dismal Swamp, flourished until an extensive bed of vegetable débris was formed. A further submergence of the area, however, depressed the protecting sandbar, permitting the Rappahannock River waters to flood the area, finally killing the swamp vegetation. During this greater submergence the upper three beds of the described section were probably deposited.

Along the Dismal Swamp canal between Deep Creek and Lilly, N. C., and also along the feeder which connects Lake Drummond and the canal, strata containing marine fossil shells are exposed. The dredge has brought up quantities of these shells in several different places. As stated on a previous page these fossils were formerly believed to belong to the Pliocene but are now regarded as of Talbot age. The matrix is a bluish-green argillaceous sand and shells are in excellent state of preservation.

The following section passed through in sinking a well just to the east of Norfolk is typical of the normal development of the Talbot formation.

Well Section near Norfolk.

			Feet
Pleistocene.	Talbot	Fine white quartz sand	18
		Blue clay	13
		Sandy clay	3½
		Loose sand	8
		Gravel with water-bearing horizon immediately overlying shell marl	7½
		Total	50

Strike, dip, and thickness.—The Talbot strata, as in the case of the Wicomico and Sunderland formations, occupy a practically horizontal position with but a slight inclination toward the main waterways of the Atlantic Ocean, the Chesapeake Bay and the tributary estuaries.

The average thickness of the formation over the greater portion of the Virginia Coastal Plain is somewhat less than 30 feet. It thickens to the eastward, however, and in the vicinity of Norfork and Portsmouth seems to be as much as 50 to 60 feet in thickness. In Accomac County on the Eastern Shore the Talbot attains its greatest thickness and as shown by somewhat generalized well records seems to be considerably more than 100 feet thick. Part of this thickness may represent the seaward portions of the earlier Pleistocene formations that were not destroyed before the Talbot was deposited. This variability in thickness is in part also explained by the uneven surface upon which the formation was deposited. The proximity of certain regions to mouths of streams during the Talbot submergence also accounts for the increased thickness of the formation in these areas.

Stratigraphic relations.—The Talbot rests unconformably in different portions of the region upon various older formations of Cretaceous-Tertiary age. It doubtless occasionally rests upon some remnants of the Lafayette, Sunderland, or Wicomico formations, although as yet no positive evidence has been found to indicate such relations to the older Pleistocene formations. In all the subaerial portion of the Coastal Plain the Talbot formation where present forms the surface material except where covered by Recent deposits of sand (sand dunes) or humus. In the submarine portion the Talbot apparently dips beneath the Recent terrace now in process of formation.

Paleontologic character.—The fossils thus far reported from the Talbot deposits in Virginia consist chiefly of marine shells from the eastern portion of the Dismal Swamp and of plant remains found in swamp deposits at many points.

Miss J. A. Gardner has determined the following molluscan forms collected from the Talbot deposits of the Dismal Swamp canal between mileposts 15 to 16.

Nucula proxima Say.
Arca transversa Say.
Arca ponderosa Say.
Abra aequalis Say.
Divaricella quadrisulcata d'Orb.
Venericardia tridentata Say.
Ostrea virginica Gmelin.
Venus mercenaria (Linné).
Tellina tenera Say.
Cumingea tellinoides (Conrad).
Ensis directus (Conrad).
Mulinia lateralis Say.
Corbula contracta Say.
Marginella limatula Conrad.
Polynices duplicatus (Say).
Crepidula plana Say.
Crepidula fornicata (Linné)
Urosalpinx cinereus (Say).
Eupleura caudata (Say).
Columbella lunata (Say).
Ilyanassa obsoleta (Say).
Nassa trivittata (Say.)
Fulgur canaliculatum (Linné).
Fulgur carica Gmelin.
Terebra dislocata (Say).
Tornatina canaliculata (Say).

In addition to the preceding species *Rangia cuneata* (Gray) has been found at Pope Creek and Newport News and *Unio* sp. on the Rappahannock River, 1½ miles below Port Royal.

Mr. E. W. Berry had also determined the following plant remains:

Taxodium distichum (Linné) Rich.	Bald Cypress
Tappahannock (seeds, cone-scales and stumps)	
Rappahannock, ½ mi. below Bayport wharf (stumps)	
Rappahannock, just above Parrotts Creek (stumps)	
Atlantic Coast, just south of Virginia Beach (stumps)	
Fagus americana Sweet	Beech
Tappahannock (nuts)	
Nomini Cliffs (leaves and burrs)	
Betula nigra Linné	Birch
Rappahannock, 1½ mi. below Port Royal (leaves)	
Hicoria glabra (Mill.) Britt.	Hickory
Tappahannock (nuts)	
Quercus sp.	Oak
Rappahannock, 1½ mi. below Port Royal (leaves)	
Nomini Cliffs (acorns)	
Celtis occidentalis Linné	Hackberry
Tappahannock (fruits)	
Vitis sp.	Grape
Tappahannock (seeds)	
Ilex Cassine Linné	Dahoon Holly
Rappahannock, 1½ mi. below Port Royal (leaves)	
Nyssa biflora Walt.	Gum
Tappahannock (seeds)	
Dendrium pleistocenium Berry	Sand Myrtle
Rappahannock, 1½ mi. below Port Royal (leaves)	

Areal distribution.—This formation has an extensive development in the Coastal Plain region of Virginia, covering all of the Eastern Shore counties of the State and the greater portion of the counties bordering Chesapeake Bay on the west and south. In addition to this wide bordering plain it is developed along all of the tide-water estuaries and often extends inland almost to the head of tide. It forms the lowest subaerial terrace of the region although wanting in many places where by recent cutting the streams have removed it forming cliffs that expose the older formations. Alexandria, Newport News, and Norfolk are all built on the Talbot plain and the formation is seen in its typical development in the vicinity of these cities.

RECENT.

The Recent deposits embrace chiefly those which are being laid down today over the submarine portion of the Coastal Plain and along the various estuaries and streams. To these must also be added such terrestrial deposits as talus, wind-blown sand, humus, and deposits forming in the swamps and bogs. In short, all deposits which are being formed today under water or on the land by natural agencies belong to this division of geological time.

The Recent terrace now under construction along the present ocean shore-line and in the bays and estuaries is the most significant of these deposits and is the last of the terrace formations which began with the Lafayette, the remnants of which today occupy the highest levels of the Coastal Plain, and which has been followed in turn by the Sunderland, Wicomico, and Talbot.

Beaches, bars, spits, deltas, flood-plains, and other formations composed of gravel, sand, clay, and peat are being built up on this terrace belt and are constantly changing their form and position with the variations in currents and winds. Along the streams flood-plains are formed that in the varying heights of the water suffer changes more or less marked. On the land the higher slopes are often covered with débris produced by the action of frost and the heavy downpours of rain which form, in certain places, accumulations of large proportions known as talus and alluvial fans.

A deposit of almost universal distribution in this climate is humus or vegetable mold, which, being mixed with the loosened surface of the underlying rocks, forms our agricultural soils. The ultimate relationship therefore of the soils to the underlying geological formations is evident.

The deposit of wind-blown sands more or less apparent everywhere, as may be readily demonstrated at every period of high winds, is especially marked along the sea coast, particularly in the vicinity of Cape Henry where sand dunes of large dimensions have been formed. The accumulation of vegetable débris in bodies of water lying in undrained regions and in ponded creeks is also considerable in many places. This is well shown in the comparatively thick deposits of partially decayed vegetation in the Dismal Swamp. Other accumulations in water and on the land are going on all the time and with those already described represent the formations of Recent time.

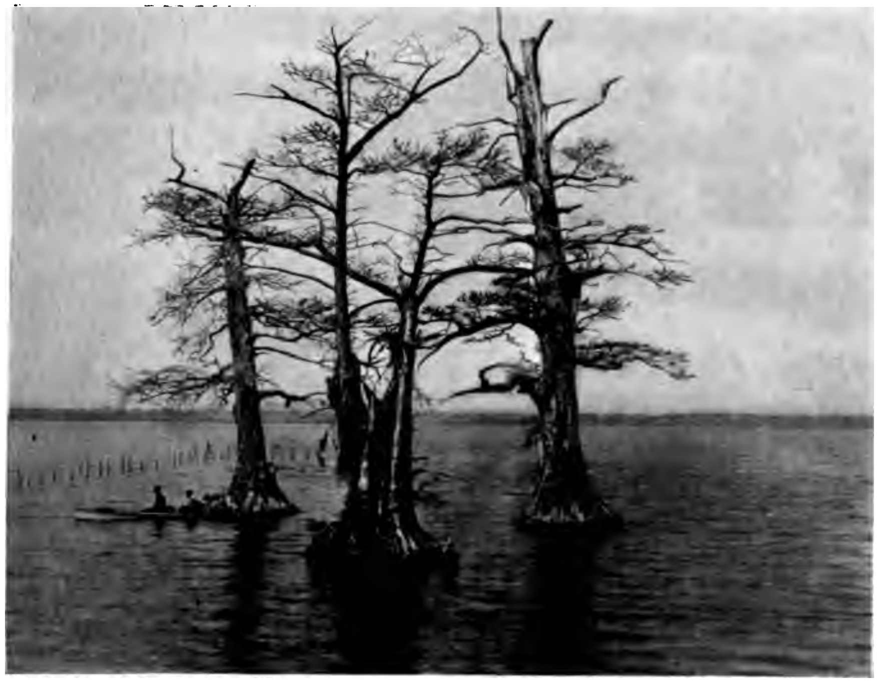

Fig. 1.—View showing large cypress trees in Lake Drummond, Dismal Swamp.

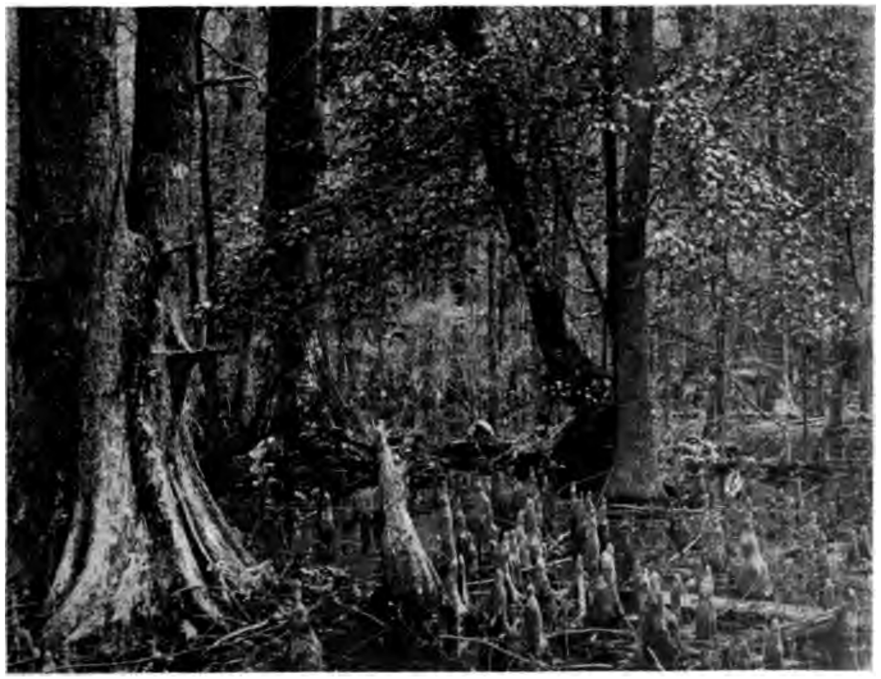

Fig. 2.—Cypress trees and knees of Dismal Swamp.

CYPRESS TREES AND KNEES IN DISMAL SWAMP.

CORRELATION OF THE VIRGINIA COASTAL PLAIN FORMATIONS

The geological formations of the Virginia Coastal Plain are closely related to those found in the adjacent states of Maryland and North Carolina and there is not a single formation in the State that cannot be traced into adjoining states and in some instances even over a wider area. Most of the formations are fossiliferous, some of them containing a great profusion of the remains either of animal or plant organisms. It is possible, therefore, in most instances to correlate the formations by the use of paleontological criteria. The Patuxent, Patapsco, Aquia, Nanjemoy, Calvert, St. Mary's, and Yorktown formations can all be correlated on this basis, while the later Lafayette and Columbia formations can only be satisfactorily correlated on the basis of physical criteria since the animal and plant remains found in the Talbot formation, although clearly of post-Tertiary age, are yet inadequate to separate the Talbot from the other Pleistocene formations.

CRETACEOUS.

The formations of Cretaceous age found in Virginia can be correlated with Cretaceous deposits elsewhere on the evidence of both lithology and paleontology. The Lower Cretaceous formations, which alone appear at the surface, afford much more satisfactory evidence for detailed correlation than do the Upper Cretaceous which have been observed only in deep-well borings far to the east of the other Cretaceous outcrops. Dr. L. W. Stephenson and Mr. E. W. Berry, under the direction of Dr. T. Wayland Vaughan, have greatly enlarged our knowledge of the stratigraphy and paleontology of the South Atlantic and Gulf States, and the results of their work have been available for the comparisons with the southern districts south of North Carolina.

LOWER CRETACEOUS.

The Lower Cretaceous formations of Virginia which have been already described under the name of the Potomac Group comprise part of the belt of Lower Cretaceous deposits which have been found over a wide area along the eastern border of the continent.

The Patuxent Formation.

The Patuxent formation is similar both in lithologic character and in fossil content to the Patuxent formation of Maryland where the deposits were first described under this name. The materials comprising the Patuxent in both areas are in a marked degree arkosic and predominantly arenaceous with layers and lenses of clay from which the plant fossils have been largely derived. The arenaceous beds are universally cross-bedded with many pebble bands and coarse beds of gravel. Overlying the Patuxent formation in Maryland is a deposit of clay, often lignitic, called the Arundel formation, that was evidently formed in the post-Patuxent valleys soon after the close of the Patuxent epoch since the flora shows few if any changes from that of the preceding Patuxent. The Arundel formation has furnished many Dinosaurian remains. The Patuxent formation includes the James River and part of the Rappahannock series as well as portions of the Aquia series earlier described by Ward.

When a comparison is instituted between the Patuxent formation of Virginia and the Patuxent and Arundel formations of Maryland the following characteristic plant fossils may be recognized as common to the two areas:

Arthrotaxopsis grandis Fontaine
Brachyphyllum parceramosum Fontaine
Cephalotaxopsis magnifolia Fontaine
Dioonites buchianus (Ett.) Born.
Nageiopsis longifolia Fontaine
Nageiopsis zamioides Fontaine
Frenelopsis parceramosa Fontaine
Equisetum Lyelli Mantell
Equisetum Burchardti (Dunk.) Brongn.
Rogersia longifolia Fontaine
Cladophlebis virginiensis Fontaine
Cladophlebis ungeri (Dunk). Ward
Ctenopteris insignis Fontaine
Nilsonia desinerve (Font.) Berry.
Podozamites distantinervis Fontaine

The Patuxent formation is represented in North Carolina by deposits which are evidently physically continuous with the Virginia strata although the formation in southern Virginia and northern North Carolina is covered at the surface by the transgression of the later Tertiary and Quaternary sediments just as it is in narrower areas in Virginia and in Maryland. The materials comprising the formation in North Carolina are similar in character but thus far no fossil remains have been found by which paleontological comparisons can be made. The senior author of this report in discussing the Lower Cretaceous formations of the Atlantic border region says:[a]

"Deposits of Lower Cretaceous age are most extensively developed in Maryland and northern Virginia, where the Patuxent (arkosic sands, gravel, clays), Arundel (clays, lignites, carbonate of iron concretions), and Patapsco (variegated clays, sands) formations occur. The organic remains consist for the most part of dinosaurs and plants. Lull, who has recently studied the former, and Berry, who has been engaged in an investigation of the latter, are agreed that they are of Lower Cretaceous age, so that the earlier questionable reference of the Patuxent and Arundel formations to the Jurassic is now abandoned. Farther southward in North Carolina is the Cape Fear formation (arkosic sands, clays), so called by Stephenson, which is evidently continuous with the Patuxent formation, although the basal beds of the Coastal plain are transgressed by later formations in southern Virginia and northern North Carolina. No fossils have been found in the Cape Fear formation, but the strata are similar lithologically to the Patuxent farther north and unlike the Arundel and Patapsco."

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[a] Clark, W. B. Bull. Geol. Soc. Amer., Vol. xx, p. 647 (1908), 1910.

The name "Cape Fear" formation, proposed for the North Carolina deposits, is now regarded as a synonym of Patuxent. The formation has also been recognized in the "Hamburg beds" of South Carolina.

The senior author of this report in discussing the correlation of the Atlantic Coast Lower Cretaceous formations with those of the Gulf says:[a]

"A correlation of the Cretaceous deposits of the Atlantic coast with those of the eastern Gulf cannot be in all instances satisfactorily made, since the Gulf Cretaceous series has never been worked out in detail, and much yet remains to be done in the determination of the range of the species. Strata hitherto called Tuscaloosa are found at the base of the Cretaceous series, in eastern Alabama as well as in Georgia, which must be regarded as identical with the Patuxent-Cape Fear formations of the Atlantic border. There is a marked unconformity at the top of the beds, and deposits supposed to represent the Eutaw, or possibly in part the Tuscaloosa farther west, are found above. Little is known regarding the western extension of these lower beds, although it is possible that they may be found beneath the surface in central Alabama, and perhaps farther westward. These older beds are, so far as known, unfossiliferous, but are now regarded as belonging unquestionably to the Lower Cretaceous."

There is little doubt therefore but that the Patuxent formation is a physicially continuous deposit from northern Delaware through Maryland, Virginia, North Carolina, South Carolina, and Georgia to eastern Alabama. Determinable fossils have only been found in the northern part of the district but further investigation may show their presence in other areas as well as in Maryland and Virginia. Among deposits containing a similar flora may be mentioned the Trinity beds of Texas, the Lakota formation of the Black Hills of Dakota and Wyoming, the Kootenai formation of British Columbia and Montana, part of the Shasta group of the Pacific coast, and the Kome beds of Greenland. It is also probable that the Morrison beds of the Rocky Mountain district belong here.

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[a] Ibid. pp. 651, 652.

There has been a prolonged discussion as to the age of these beds since Professor Marsh considered the Dinosauria found in the overlying Arundel formation in Maryland to possess Jurassic affinities. The paleobotanists, on the other hand, have consistently maintained the Lower Cretaceous age of the deposits, basing their conclusions on the extensive flora which is closely similar to that found in the Neocomian beds of Portugal, Mexico, and Japan and in the Wealden deposits of England and Germany, now generally regarded as of Lower Cretaceous age. More recent studies of the Dinosauria have led Professor Lull to regard them also as of Lower Cretaceous age and the Patuxent formation is therefore referred to that horizon in this report.

The Patapsco Formation.

The Patapsco formation in Virginia is similar lithologically to the formation thus named in Maryland while the flora of the two areas is practically identical. The deposits in both regions consist of highly colored and variegated clays which grade over into highly colored arenaceous clays, while coarser sandy beds are at times interstratified.

The Patapsco formation includes the Mt. Vernon and part of the Aquia series of Ward; also part of Fontaine's Rappahannock series.

Among the more important plant fossils found common to the two areas are:

Acrostichopteris longipennis Fontaine
Araucarites aquiensis Fontaine
Araliaephyllum magnifolium Fontaine
Araliaephyllum crassinerve (Fontaine) Berry
Celastrophyllum parvifolium (Fontaine) Berry
Celastrophyllum acutidens Fontaine
Nelumbites tenuinervis (Fontaine) Berry
Nelumbites virginiensis (Fontaine) Berry
Populophyllum minutum Ward
Pinus vernonensis Ward
Sapindopsis brevifolia Fontaine
Sapindopsis magnifolia Fontaine
Sapindopsis variabilis Fontaine
Sassafras parvifolium Fontaine
Widdringtonites ramosus (Fontaine) Berry
Hederaephyllum dentatum (Fontaine) Berry
Podozamites lanceolatus (L. & H.) Schimper

The Patapsco deposits are not known on the Atlantic seaboard to the south of the James River area but extend northward across Maryland and Delaware into Pennsylvania, their most northern occurrence being isolated outcrops in certain of the deeper valleys to the west of Philadelphia.

The Patapsco formation is in all probability to be correlated with the Fuson formation of the Black Hills while it represents a part of the marine Lower Cretaceous of the western Gulf and Pacific coast regions.

The flora according to European standards has a marked Albian facies, presenting many points in common with the Albian of Portugal described by Saporta, several species as well as many genera being identical.

UPPER CRETACEOUS.

The Upper Cretaceous deposits of Virginia have been observed only in deep-well borings near the eastern border of the Coastal Plain, the Lower Cretaceous being directly overlain unconformably along the line of outcrop by the overlapping Tertiary formations. The senior author of this report in discussing the Upper Cretaceous of the Atlantic border region says:[a]

"Upper Cretaceous deposits extend from New Jersey, where they are most extensively developed, northeastward along the New England coast and southward through Delaware and Maryland to the Potomac valley. Strata of this age have been penetrated in well borings in eastern Virginia, but do not appear along the line of outcrop, being overlapped by Tertiary formations. In North Carolina Upper Cretaceous deposits again appear, and cover a wide area to the south of the Hatteras axis.

"The Raritan formation (clay, sands, gravels) of the northern part of the Coastal plain evidently represents the earliest phase of Upper Cretaceous deposition, these beds overlying the Lower Cretaceous strata, where exposed, with a marked unconformity. Beds of similar age do not occur in North Carolina.

"The overlying Magothy-Matawan formations (sands, clays, lignitic and glauconitic beds), which outcrop throughout the area from the Potomac basin northward to the islands off the New England coast, are represented in North Carolina by the Black Creek formation (sands, clays, lignitic and glauconitic beds), the same fauna and flora characterizing the deposits in both areas. The minor subdivisions established in New Jersey, where these formations are best developed can not be recognized elsewhere, and the changes in physical conditions bringing about the differentiation of faunules there described were evidently only local.

"The Monmouth formation (glauconitic beds, sands, clays) characterized by the introduction of *Belemnitella americana* and other forms can be traced through New Jersey, Delaware, and Maryland, and again reappears in North

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[a] Op. cit. pp. 647-648.

Carolina, the deposits here and in South Carolina having been named the Peedee formation (glauconitic beds, sands, clay). The reappearance of one of the earlier faunules toward the close of the Monmouth, as observed in New Jersey, is wanting.

"The Rancocas and Manasquan formations (glauconitic and calcareous beds) of the northern part of the Coastal plain are chiefly found in New Jersey and Delaware, and contain a younger fauna. Such late Cretaceous strata are not known elsewhere along the Atlantic border."

The Virginia deposits belong to the Magothy-Matawan-Monmouth series of formations but the exact position of the beds cannot be satisfactorily determined although they probably belong to the lower rather than to the upper portion of this series, the character of the materials suggesting the Matawan formation. More paleontological evidence is required to finally determine this point.

The senior author of this report in discussing the correlation of the deposits with those of the Gulf and other areas says:[a]

"Reference has already been made to the fact that the Magothy-Matawan-Monmouth formations of the northern part of the Coastal Plain are to be correlated with the Black Creek-Peedee formations of North Carolina. It seems equally certain that these find their counterpart in the Tuscaloosa-Eutaw- Ripley of the eastern Gulf, with the exception of such portion hitherto referred to the Tuscaloosa as is known to be of Lower Cretaceous age.

"Very little is known of the fauna of the earliest marine sediments commonly referred to the Eutaw, although the few fossils found come from apparently interstratified marine beds not unlike those in the Black Creek and the Magothy. It is also apparent that the fauna of certain strata of the lower portions of what has been regarded as Ripley, on the Chattahoochie River, represents the Black Creek and the Magothy-Matawan, but whether these beds should be considered Ripley or as representing part of an earlier horizon, and thus included in the Eutaw, can only be determined by further investigations.

"It is largely a question, in any event, as to whether the term Ripley or Ripleyan shall be used in a broad way to include the beds containing both the lower and upper faunas, in which case even the Eutaw would have to be regarded as Lower Ripley, or whether two formations are to be recognized to be called Ripley and something else, either Eutaw or Tombigbee, as certain stratigraphic and paleontologic facts suggest. Continuous sedimentation, with gradual change in the character of the materials until the beds became wholly or at least largely marine, doubtless continued during the life of these faunas here, as in the other areas, and such facts as are available point to this conclusion. Such being the case, the term Ripleyan might perhaps with greater propriety be applied, as has been frequently done to the entire fauna, if it seemed inadvisable to restrict it, in which event a new formational name would have to be employed for the upper beds. It is evident that the greater part of the deposits comprising the Tuscaloosa must of necessity be associated with the Upper Cretaceous strata of the Gulf region, and a group term to include this entire series of deposits would not be inappropriate. A final decision on these points, as well as a satisfactory correlation of the Middle Atlantic with the Eastern Gulf deposits must be deferred, however, until more is known of the stratigraphy and paleontology of the latter region.

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[a] Op. cit. pp. 652-654.

"When a comparison of the Atlantic Coast Cretaceous fauna is made with that of the European Cretaceous we find that its general character is that of the Senonian, and the view has been commonly held by invertebrate paleontologists that all of the marine beds of the Atlantic and Eastern Gulf coasts represent that epoch of the Cretaceous, with the possible exception of certain later deposits in New Jersey which have been regarded by the writer and others as of Danian age. Some even include in the Senonian all of the Upper Cretaceous strata, both marine and non-marine, from New Jersey to the Mississippi basin, since even the lowest known Upper Cretaceous deposits in this area (Raritan formation) contain a few marine invertebrates of possibly identical species with those of higher horizons. Those who hold this view necessarily consider that the earlier Turonian and Cenomanian epochs are unrepresented, since every one now agrees that the unconformably underlying deposits are Lower Cretaceous. It is quite possible, however, that a more exhaustive study of these faunas may show them to be in part of pre-Senonian age.

"It is essential, however, before passing final judgment on the basis of marine invertebrates to examine the evidence furnished by the fossil plants which occur in great variety in the lowest beds beneath those containing the marine invertebrates, as well as in interbedded strata in the middle of the series. Berry, who has been engaged in a comparative study of the Cretaceous floras of the Atlantic and Gulf coasts, states that the Magothy-Black Creek flora is identical with that of the Tuscaloosa-Eutaw. Not only do they have the same floral characteristics, but the species are in a larger number of instances identical. Furthermore, the same forms occur in the Woodbine formation in Texas and in the Dakota beds of the West. The flora has been regarded as characteristically Cenomanian, although it may represent the somewhat meager Turonian flora which succeeds it, and therefore belong to that horizon. On the other hand, it is distinctly older than the Montana flora of the West and its Senonian equivalent in Europe.

"The evidence afforded, therefore, by the invertebrates and plants is apparently in conflict, since the former present a Senonian facies throughout, according to many invertebrate paleontologists, while the latter are regarded by paleobotanists to be characteristically Cenomanian, or possibly Turonian, in age. In this connection we find in the western Gulf that the Woodbine formation, which is the representative of the Dakota sandstone farther west, and which contains, as already pointed out, a Black Creek-Magothy-Tuscaloosa flora, is succeeded by marine beds known as the Eagle Ford and Austin Chalk formations which represent the Colorado group farther west, and that these are again succeeded by deposits containing the Ripley fauna, the latter being regarded as the equivalent of the Montana group of the Rocky Mountain district. Since the Dakota has been generally regarded as containing a Cenomanian flora and the Montana a Senonian fauna and flora, the Colorado and its equivalents have been assigned to the Turonian. As the Montana flora is considered by paleobotanists as quite distinct from and much younger in its facies than the Dakota, it is difficult to see, if we are not to ignore the evidence of paleobotany, how, as some have supposed, the entire series of Upper Cretaceous sediments on the Atlantic and Eastern Gulf coasts can be assigned to the Senonian. Such a conclusion is still further weakened by the fact that the Woodbine beds may be stratigraphically continuous beneath the Mississippi embayment with the Tuscaloosa deposits farther east in which the same flora occurs. A much more exhaustive study of the stratigraphy of the Cretaceous deposits of the Central and Western Gulf regions is clearly demanded, therefore, before these questions can be finally settled.

"It is apparent, in any event, that we are still forced to consider the possibility of the Upper Cretaceous sediments of the Atlantic and Eastern Gulf coasts representing horizons earlier than the Senonian. Since the Turonian has not been recognized by either a distinct fauna or flora in the series of conformable strata under consideration, it is quite possible that a Cenomanian flora, once established, continued its existence in America later than the close of the Cenomanian epoch in Europe. At the same time it is conceivable that the earlier elements of the invertebrate fauna are somewhat older than paleozoölogists have recognized, and that a greater or less portion of the series under discussion must therefore be regarded as Turonian. The evidence of the plants is certainly favorable to this interpretation, as the European Turonian flora, although a very sparse one, presents some marked points of agreement with portions of the flora under consideration."

Table of Cretaceous Formations.

	Long Island and southern New England	New Jersey	Delaware and Maryland	Virginia	North Carolina	Alabama
Upper Cretaceous		Manasquan				
		Rancocas	Rancocas			
		Monmouth	Monmouth		Peedee	Ripley Selma
	Matawan	Matawan	Matawan		Black Creek	Eutaw
	Magothy	Magothy	Magothy			Tuscaloosa
	Raritan	Raritan	Raritan			?
Lower Cretaceous			Patapsco	Patapsco		?
			Arundel			Lower Cretaceous
			Patuxent	Patuxent	Patuxent	?

TERTIARY.

The Tertiary deposits of Virginia represent both the Eocene and the Miocene and also doubtfully the Pliocene in the Lafayette formation. All of the Eocene and Miocene formations are very fossiliferous so that comparisons can be made with well-known faunas elsewhere while the correlation of the Lafayette formation is based entirely on physical grounds.

Eocene.

The Virginia Eocene formations already described under the name of Pamunkey group are limited to the province comprising Virginia, Maryland, and Delaware and already described by the senior author of this report.[a]

The same author in discussing the district from New Jersey to North Carolina in a recent paper says:[b]

"The Eocene deposits of New Jersey, known as the Shark River formation (glauconitic beds), apparently overlie the Manasquan formation conformably. The contained fossils show the beds to be of early Eocene age. Farther south in Maryland and Virginia, but nowhere in contact with the Shark River beds, is a series of younger and conformable Eocene deposits known as the Aquia and Nanjemoy formations (glauconitic beds, clays, sands), which overlie the Cretaceous unconformably. Entirely discontinuous are the North Carolina Eocene strata, which Miller has named the Trent and Castle Hayne formations (calcareous marls, clays), and which are of still later Eocene age. The latter are apparently unconformable to each other, and likewise rest unconformably on Cretaceous deposits."

The Aquia Formation.

The Aquia formation can be traced from southern Virginia across Maryland to the Delaware border. The materials throughout this area are similar and the fossils identical. Both to the north and to the south of this region the Aquia formation is transgressed by later deposits and does not again appear at the surface. Among the characteristic fossils are:

Pleurotoma potomacensis Clark and Martin
Turritella mortoni Conrad
Panopea elongata Conrad
Meretrix ovata var. *pyga* Conrad
Dosiniopsis lenticularis (Rogers)
Venericardia planicosta var. *regia* Conrad
Crassatellites alaeformis (Conrad)
Pholodomya marylandica Conrad
Modiolus alabamensis Aldrich
Ostrea compressirostra Say
Cucullaea gigantea Conrad

The Aquia formation affords many species identical with those of the Wilcox of the Gulf, the fossils on the whole being more characteristic of the lower division although a number of forms are found only in the upper Wilcox and Claiborne horizons in Alabama. It is evident that many of the species common to the two areas differ widely in their geological range. This is evidently due in part to the difference in physical conditions in the Gulf and middle Atlantic regions and in part, in all probability, to migration. It is apparent, however, that the fauna of the Aquia formation is more closely related to the Wilcox than to earlier or later horizons and that there is a somewhat closer resemblance to the lower than to the upper Wilcox.

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[a] Clark, W. B. Bull. U. S. Geol. Survey, No. 141, 1896; Clark and Martin, Md. Geol. Survey, Eocene, 1901.

[b] Clark, W. B. Bull. Geol. Soc. Amer., Vol. xx, p. 649 (1908), 1910.

The correlation of the Aquia formation with European deposits is even less definite. Dall correlates[a] the entire middle Atlantic coast Eocene with the Suessonian of Europe. It is doubtful, however, whether the Nanjemoy formation should be thus correlated since the writers believe that the Eocene deposits of Virginia and Maryland represent more than the Wilcox of the Gulf and therefore must be regarded as having a wider range in the European Eocene.

The Nanjemoy Formation.

The Nanjemoy formation has been recognized in Virginia and in southern Maryland, the materials and fossils being characteristic of the deposits throughout this area. Among the typical forms found in the two states are:

Corbula aldrichi Meyer
Meretrix ovata var. *ovata* (Rogers)
Meretrix subimpressa Conrad
Lucina dartoni Clark
Venericardia potapacoensis Clark and Martin
Ostrea sellaeformis Conrad
Leda improcera (Conrad)
Leda potomacensis Clark and Martin
Nucula potomacensis Clark and Martin

The Nanjemoy formation affords species that are characteristic of the upper Wilcox and the lower Claiborne although the relationships are on the whole closer with the former than with the later. It is possible that both may be represented.

The correlation of the Nanjemoy formation with the European Eocene cannot be satisfactorily made. It is possible that it represents a somewhat higher horizon than the Suessonian and may represent the Londonian and even in part the Parisian. The difficulty in correlating the middle Atlantic Coast Eocene deposits with those of Europe is due to the fact that the few identical species in the two areas have a wide geological range and are thus of little value for purposes of detailed comparison. Other common species may ultimately be found but more exhaustive collections than have been made will be necessary. Until such investigations are completed the correlation of the deposits on the two sides of the Atlantic can be at best only provisional.

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[a] 18th Ann. Rept. U. S. Geol. Survey, part 2, pp. 327-348, 1898.

The Trent and Castle Hayne formations are younger than the Virginia Eocene formations and evidently represent the Jackson and possibly in part the upper Claiborne as well. A more exhaustive study of the fossils is necessary before an exact correlation can be made.

Table of Eocene Formations.

New Jersey	Delaware and Maryland	Virginia	North Carolina	Alabama
			Castle Hayne Trent	Jackson Claiborne
	Nanjemoy Aquia	Nanjemoy Aquia		Wilcox
Shark River				Midway

MIOCENE.

The Miocene formations of Virginia are in part continued into Maryland[a] and Delaware on the north and in part into North Carolina on the south. The senior author in discussing the formations in this district says.[b]

"The Miocene deposits are best developed in the Chesapeake Bay region, where four formations have been recognized, known as the Calvert (clays, sandy clays, diatomaceous earth, shell marls), the Choptank (sandy clays, sands, shell marls), the St. Mary's (sandy clays, sands, shell marls), and the Yorktown (fragmental shell marls, sandy clays, sands). The Choptank does not occur in Virginia, and the Yorktown is absent in Maryland. These formations are evidently continued in part into New Jersey, as similar faunas have been found there, but the relationships have not been fully worked out as yet. To the southward the St. Mary's and Yorktown formations, transgressing the earlier deposits, continue on into North Carolina, both being found over extensive areas to the north of the Hatteras axis, where the Yorktown overlies the St. Mary's unconformably. To the south of the Hatteras axis deposits very similar to the Yorktown formation, both lithologically and paleontologically, but known under the name of the Duplin formation, are found resting unconformably on pre-Miocene formations."

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[a] Clark, Shuttuck, and Dall. Md. Geol. Survey, Miocene, 1904.

[b] Clark, W. B. Bull. Geol. Soc. Amer., Vol. xx, p. 649, 1908.

The Calvert Formation.

The Calvert formation is practically continuous with deposits thus named in Maryland and Delaware. Both the materials and the fossils are similar in the two areas although some forms are found in Maryland which do not occur in Virginia and the same is true regarding a number of Virginia species. Deposits containing similar forms are found in southern New Jersey where they have been described under the name of Kirkwood formation.

The Calvert deposits are not known in North Carolina, the St. Mary's formation transgressing the Calvert before the southern limits of Virginia are reached. All of the Miocene deposits in North Carolina so far as known belong to much more recent horizons. Dr. T. W. Vaughan[a] has identified Sloan's Marks Head marl at Porter's Landing, Savannah River, Georgia, as the approximate equivalent of the Calvert which would indicate the presence of deposits of this age in the south Atlantic district.

The correlation of the Atlantic coast Miocene with the Miocene deposits of Europe has not been attempted in detail and there are many points of difference that make such correlation difficult. Dall states that in a general way, allowing for local peculiarities, the Miocene of north Germany compares well and agrees closely with that of Virginia. Berry who has determined the plant remains from the Calvert formation of Virginia regards them as equivalent to the middle Miocene of central Europe.

The St. Mary's Formation.

The St. Mary's formation contains the same materials and faunas over a wide area to the north of the Hatteras axis and has been traced almost continuously from North Carolina across Virginia and Maryland into Delaware while St. Mary's forms have also been found in the deep wells of eastern New Jersey. The absence of the Choptank formation in Virginia brings the St. Mary's fauna into sharper contract with the underlying Miocene than in Maryland. The faunas are not identical in all particulars in the two areas, some species found only at lower horizons in Maryland continuing on into the St. Mary's in Virginia.

The St. Mary's formation does not appear as far as known, to the south of the Hatteras axis in North Carolina but Dr. T. W. Vaughan considers the Edisto beds of South Carolina as probably of the same age.

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[a] Science, N. S., Vol. 31, pp. 833, 834, 1910.

The Yorktown Formation.

The Yorktown formation can be traced from southern Virginia southward into North Carolina, the same materials and fauna persisting, but it is unknown in northern Virginia and Maryland. To the south of the Hatteras axis the Duplin formation is closely related to the Yorktown deposits. Dr. Dall[a] in discussing this relationship says:

"A study of these (fossils from the Natural Well) indicated their general parallelism with the upper or Yorktown Miocene of Virginia, with which their deposition may have been partially synchronous. The fossil species, are, however, largely distinct from those of the Yorktown beds and of a more tropical aspect. It is probably that in Miocene times, as at the present day, there was a difference in the marine faunas of the two regions, that at Yorktown and Suffolk being more allied to the subjacent temperate fauna of the older Miocene of Maryland and Virginia, while that in North Carolina contained more southern types. Yet even this seems hardly sufficient to account for more than part of the difference. It is probable that with the elevation of the Gulf and Florida coasts, which closed the deposition of the cold-water Miocene on those shores, the changes in ocean currents which made the water warmer and invited the return of the subtropical fauna, banished at the end of the Oak Grove epoch, extended at least as far as North Carolina. To this change I ascribe part of the new aspect of the Duplin fauna, which would thus be due to the combination of two factors."

As already stated a correlation of the Atlantic coast with European Miocene deposits cannot be readily made although according to Dall "the Miocene fauna of Northern Germany compares well and agrees closely with that of Maryland (and Virginia), while the Mediterranean Miocene finds a closer analogue in the more tropical fauna of the Duplin beds of the Carolinas."

Table of Miocene Formations.

Maryland	**Virginia**	North Carolina
	Yorktown	Yorktown and Duplin
St. Mary's	St. Mary's	St. Mary's
Choptank		
Calvert	Calvert	

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[a] Wagner Free Institute of Science, Trans.. Vol. ii, pt. 6, pp. 1598-1603.

PLIOCENE (?).

The Lafayette Formation.

The Lafayette formation is similar both in its materials and physiographic relations to deposits which have received the same name throughout the Atlantic and Gulf borders. The formation occupies a relatively narrow belt along the western margin of the Coastal Plain and at times occurs in isolated areas on the Piedmont Plateau. It forms the oldest and highest of the series of the late Tertiary and Quaternary terraces that characterize the Coastal Plain. In the absence of fossils this physiographic feature becomes one of the most important criteria for the correlation of the formation. The structure and composition of the strata already described are also highly characteristic and aid materially in the recognition of this formation whereever found.

The age of the Lafayette formation is in much doubt. From its known stratigraphic relations it is evidently younger than the latest Miocene beds and probably younger than the marine Pliocene of the Atlantic border. These earlier beds were apparently subjected to a long period of erosion before the deposition of the Lafayette began. Again, after the close of the Lafayette it is probable that an extensive epoch of erosion occurred before the Columbia deposits of Pleistocene age were laid down. This would assign to the Lafayette formation a position between the marine beds of Pliocene age and the oldest deposits of recognizable Pleistocene age. The Lafayette formation is therefore either of late Pliocene or early Pleistocene age. The consensus of opinion hitherto has been in favor of the former interpretation but in the absence of fossils it is practially impossible to reach a positive conclusion. It is evident that more adequate evidence must be secured before the question can be regarded as settled, especially, as Berry has shown, as has previously been mentioned, that the type sections in Lafayette County, Miss., are of Eocene age, thus necessitating a new name for the later Atlantic coast deposits.

QUATERNARY.

The Quaternary formations of Virginia comprise both Pleistocene and Recent deposits. Since they represent the most recent phase of deposition and still preserve in a marked degree their original form, physiographic criteria are of much importance in interpreting and correlating the deposits.

PLEISTOCENE.

The Pleistocene formations already described under the name of the Columbia Group have been recognized over a wide area along the Atlantic seaboard south of the terminal moraine of the last glacial period. The distribution and origin of these deposits along the continent border have been discussed by Dr. G. B. Shattuck.[a]

The senior author of this report has recently discussed the correlation of the Pleistocene formations in the Middle Atlantic Coast area. He says:[b]

"The Pleistocene deposits consist chiefly of a series of terraces, the earliest found along the western border of the Coastal Plain, encircling the margin of the Piedmont plateau and the higher elevations of the Coastal Plain, and extending up the estuaries and streams, where it finally merges into fluviatile deposits. This oldest terrace, known as the Sunderland formation, can be traced from the glacial deposits southward across Maryland and Virginia into North Carolina. The Sunderland terrace, which has an elevation of 150 to 200 feet along its shoreward margin, declines gradually seaward and toward the larger valleys, where it reaches to below 100 feet in height. Another terrace is found in central and southern North Carolina between the Lafayette and Sunderland and has been named the Coharia formation by Stephenson.

"The next younger terrace, known as the Wicomico, encircles the preceding terrace at a lower elevation, and forms a well marked belt along the eastward margin of the latter although extending up the river channels in some places to the Piedmont border, where it also merges into fluviatile deposits. Its landward margin has an elevation of 80 to 110 feet, from which point it declines seaward and toward the larger stream valleys to 50 to 60 feet in elevation. Its surface is not as extensively dissected as the Sunderland terrace, and near its inner margin are found many buried valleys that were cut at the close of Sunderland time.

"Below the Wicomico terrace, and encircling it, is the third or youngest terrace of the Pleistocene, which has been called the Talbot. The landward margin of the Talbot terrace is from 40 to 60 feet in height, from which elevation it gradually declines seaward until it reaches nearly, if not quite, to sea-level. The Talbot terrace has been but slightly dissected, compared with the earlier terraces, and forms the coastal lowlands. It may also be traced as a low terrace far up the estuaries and river valleys until it also merges into true fluviatile deposits. In North Carolina it divides into two terraces, constituting the Chowan and Pamlico formations.

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[a] Amer. Geol., Vol. xxviii, pp. 87-107, 1901; Md. Geol. Survey, Pliocene and Pleistocene, pp. 291, 1906.

[b] Clark, W. B. Bull. Geol. Soc. Amer., pp. 650, 651 (1908), 1910.

"All of these Pleistocene formations have been traced step by step throughout the area in question, and present the same general characters everywhere."

The Sunderland Formation.

The Sunderland formation, like the Lafayette formation, can only be correlated on the basis of physical criteria. The more or less dissected terrace surface has been traced from Delaware southward across Maryland and Virginia into North Carolina.

The materials comprising the Sunderland formation are similar to those found to the northward although some changes occur due to differences in the character of the rocks from which the sediments were derived. Its position enwrapping the higher portion of the Coastal Plain beneath the Lafayette formation is closely similar to the Sunderland of more northern districts. This oldest of the Pleistocene terraces is everywhere more highly dissected than the later terraces at lower levels while the materials as a whole are somewhat more extensively disintegrated, although this factor must be employed with care since similarly decayed materials are often to be found in later deposits.

The Sunderland formation corresponds approximately with the Earlier Columbia of McGee and Darton and with parts of the Bridgeton and Pensauken as described by Salisbury in New Jersey.

The age of the Sunderland and later terraces has been generally recognized as Pleistocene. The fossil leaves of the Sunderland belong mostly to living species while the relatively small physical changes that have occurred indicate that the deposits cannot be older than Pleistocene. Furthermore its probable contemporaneity with pronounced glacial conditions is evidenced by the striated boulders sometimes found in the deposits. Whether they represent the earliest phase of Pleistocene deposition has not been settled and cannot be until the age of the Lafayette formation is finally determined.

The Wicomico Formation.

The Wicomico formation is devoid of fossils of correlative value. Its equivalency with the deposits similarly named in Maryland is shown by its terraced surface occupying a position at approximately the same level and beneath the Sunderland terrace already described. It enwraps the earlier terrace often with a pronounced escarpment throughout the central and northern Coastal Plain and has been traced continuously from the valley of the Deleware River across Delaware, Maryland, and Virginia into North Carolina. The surface of the Wicomico terrace is less dissected than that of the Sunderland and in general the materials are less decayed.

The few plant fossils found in the Wicomico formation belong essentially to living species although in a few instances they seem to be ancestral types that have since become differentiated into those living in the sand barrens and in the upland country. The differences, however, are so slight that there is no question but that the flora as a whole must be referred to the Pleistocene. The presence of ice-borne boulders furnishes evidence for its probable contemporaneity with the ice-invasion although the particular drift sheet with which the formation should be correlated has not yet been determined.

The Wicomico represents the upper portion of the Later Columbia formation of McGee and Darton and a part of the Pensauken formation of Salisbury.

The Talbot Formation.

The Talbot terrace as already described is found at a lower level than the Wicomico and enwraps the same extending up the valleys until it merges into the fluviatile deposits of the Coastal Plain streams as in the case of the preceding Pleistocene terraces. It can be traced all the way from the Delaware valley across Delaware, Maryland, and Virginia to the North Carolina line.

The Pleistocene age of the formation is proved by the molluscan fossils found along the Dismal Swamp canal and at Cornfield Harbor on the Potomac River, most of which belong to species still living in the adjacent sea. Its Pleistocene age is further shown by its evident contemporaneity with a part of the ice-invasion of the northern part of the country, as evidenced by the numerous ice-borne boulders found in its deposits. The formation represents the lower part of the Later Columbia described by McGee and Darton and corresponds to the Cape May and part of the Pensauken formations of Salisbury.

In North Carolina two mappable terrace deposits have been found below the Wicomico level. To these, the names, Pamlico and Chowan, have been applied. Together they seem to be the equivalent of the Talbot and the explanation seems to be found in a halting during the uplift following the deposition of the main portion of the Talbot which permitted the ocean waves to cut a cliff that still persists over extensive areas south of the

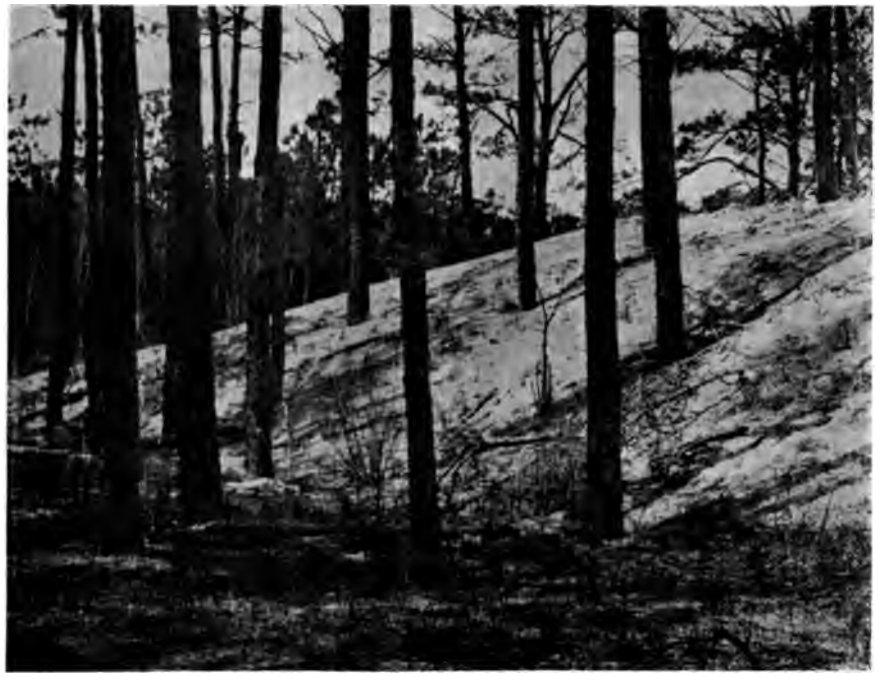

Fig. 1.—View of sand dunes, Cape Henry.

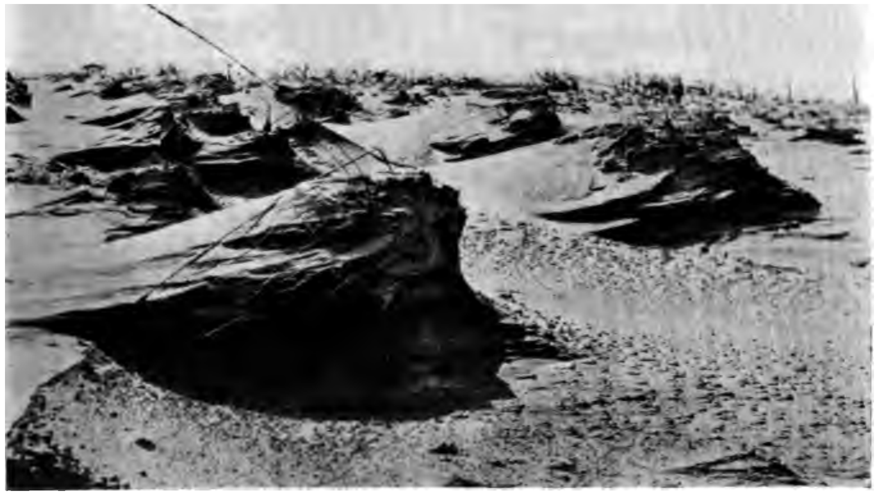

Fig. 2.—View of sand dunes, Cape Henry.

SAND DUNES, CAPE HENRY.

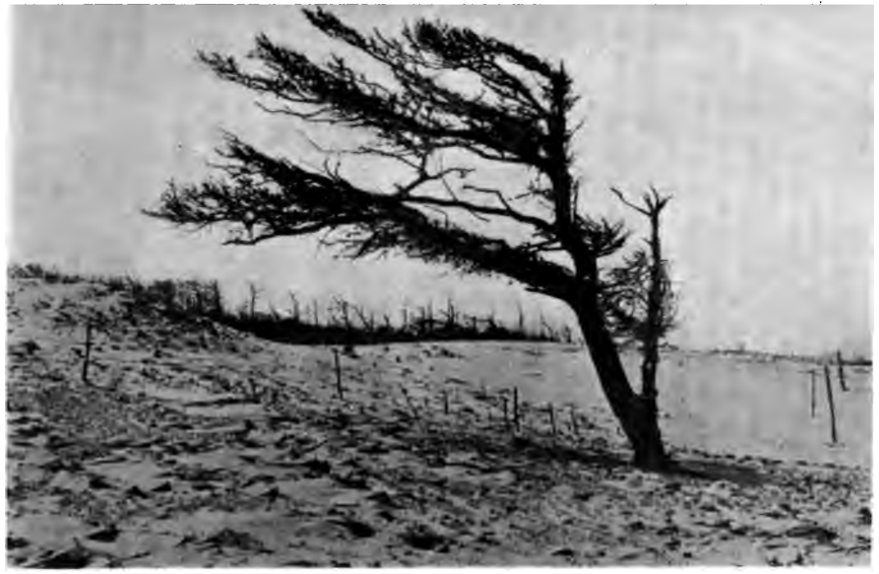

Fig. 1.—View of sand dunes, Cape Henry.

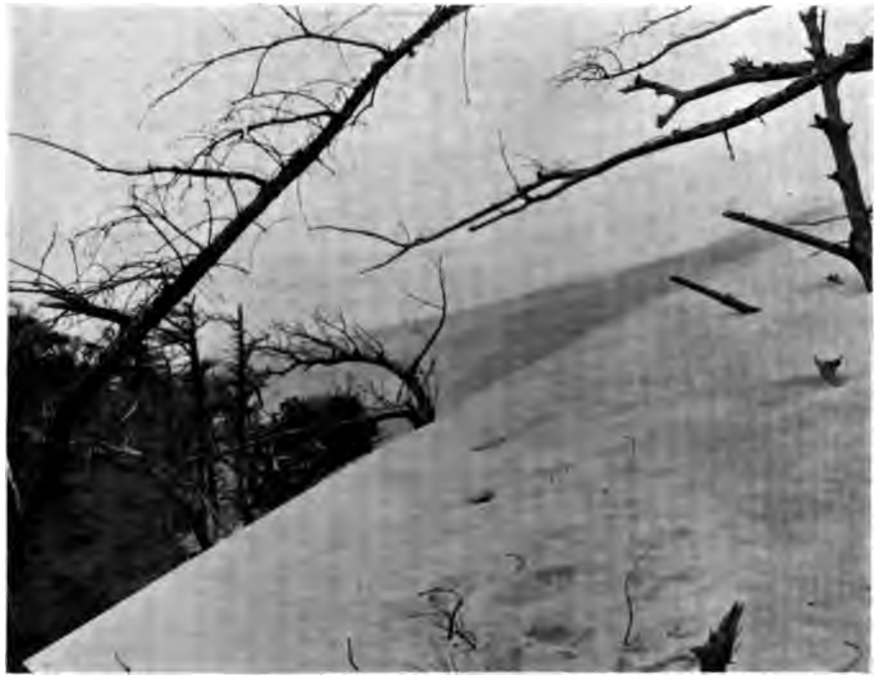

Fig. 2.—View of sand dunes, Cape Henry.

SAND DUNES, CAPE HENRY.

Virginia line. Indications of such a division of the Talbot can be observed in a few places in Virginia but are not distinct enough to be mapped. Unlike conditions in the two adjoining regions give evidence of the differential movements that took place during the uplifts and submergences of the Pleistocene.

Table of Pleistocene Formations.

	Delaware and Maryland	Virginia	North Carolina
Columbia	Talbot	Talbot	Pamlico Chowan
	Wicomico	Wicomico	Wicomico
	Sunderland	Sunderland	Sunderland
			Coharie

RECENT.

The recent deposits consist of beaches, sand bars, sand spits, sand dunes, flood plains and other fluviatile deposits, and humus. These deposits represent the results of all the geological agencies now at work in modifying the surface of the Coastal plain, and are variously developed in the different portions of the region, dependent on the character of the adjacent formations and the distribution of the various streams and currents. A great Recent terrace, similar in all particulars to those of Pleistocene date, is now being laid down beneath the bed of the present sea and estuaries and along the border of the coast and tidal streams. Beaches are frequently being formed, while great sand bars are common. Sand dunes adjoin the coast, and are especially prominent in southern Virginia and North Carolina, where from Cape Henry southward they are a conspicuous feature of the coastal topography. The rivers during flood are constructing flood plains, which coalesce with the deposits of the estuaries. Over the land surface the transfer of material and the development of soils, with their accompanying humus, are going on everywhere.

GEOLOGICAL HISTORY OF THE VIRGINIA COASTAL PLAIN

The formations which occur within the Virginia Coastal Plain are in every case continued either to the north or to the south and the geologic history which is here outlined has been based on work done not only in the Virginia area but also throughout the entire region of the North Atlantic Coastal Plain from New England to the Carolinas.

A study of the geologic history of the region shows that it has been a long and complicated one. This is evidenced by the many different kinds of strata represented and by the relations which they bear to one another. There are deposits that were plainly formed in fresh or brackish water, while others show evidence of deposition in marine waters; some have been deposited in water of shallow depth, others in deeper water; while breaks in the continuity of the different strata indicate that the region has been subjected to many elevations and subsidences from the time of the formation of its earliest rocks down to the present day.

Pre-Cretaceous history.—The oldest Coastal Plain deposits are of Lower Cretaceous age. They can be found everywhere resting upon crystalline rocks of probably pre-Cambrian and early Paleozoic age. These form the floor upon which the Coastal Plain deposits have been laid down, a floor which near the present shore-line lies about 2,000 feet beneath the sea level, but which rises to the west and finally appears at the surface to form the Piedmont Plateau, the physiographic province which forms the western boundary of the Coastal Plain.

In the Piedmont it is exceedingly difficult to interpret the past history for the reason that the whole area has been subjected to many great changes which have essentially modified original materials, yet the studies that have been carried on have revealed many facts concerning the original conditions of the rocks now composing it. Many of these were originally sedimentary deposits, but in the processes of metamorphism have now lost nearly all traces of their original character. Furthermore these old sedimentaries have been broken through in many different places by igneous materials which have also been greatly altered. Thus the Piedmont metamorphics contain representatives of both igneous and sedimentary rocks. Time and again they have been subjected to the various processes of metamorphism by which the original mineral composition has been greatly changed, and the beds have been folded and crumpled.

During the latter portion of the Paleozoic era the Piedmont floor of the Coastal Plain and also the present Piedmont Plateau seem to have formed a land surface which probably extended far to the east of the present shoreline. How much farther we do not know, but perhaps to the edge of the present continental shelf. The streams draining this land-mass carried great quantities of terrigenous materials to the west where they were deposited in the Paleozoic sea. These strata now form the Blue Ridge and Allegany Plateau of the western portion of the State. During part of the Triassic period a shallow estuary was formed near the eastern margin of the present Piedmont Plateau, into which some of the streams carried their load of sediment, and along the margin of which marsh plants grew in such abundance that their remains now form the coal beds in the vicinity of Richmond.

It is of course possible that other changes occurred during the Paleozoic and early Mesozoic periods which have left no record. The region may have been depressed beneath the ocean waters and covered with sediments many times, but if such is the case, later erosion has removed them from that portion of the crystalline surface accessible to our study. Whether sediments of later Paleozoic and early Mesozoic age overlie the older crystallines to the east of the present coast line cannot be with absolute certainty determined but it is within the range of possibility.

Early Cretaceous history.—The recorded history of the Virginia Coastal Plain begins with early Cretaceous time. The earliest of the known unconsolidated deposits lying upon the floor of crystalline rocks belong to the Patuxent formation of the Potomac Group. These deposits indicate a submergence of the entire Coastal Plain to perhaps a short distance beyond the "fall line." The water covering the region was shallow and seems to have been estuarine in character. The cross-bedded sands and gravel furnish evidence of the shifting currents as do also the rapid changes in the character of the materials both horizontally and vertically. The presence of numerous land plants in the laminated clays shows the proximity of the land. Since the Patuxent deposits are so very extensive it is somewhat difficult to explain the physical conditions then prevailing. It has been suggested that possibly there was a land barrier somewhere to the east, probably beyond the present Atlantic shore-line, which kept out the ocean waters. The presence of large quantities of lignitic material seems to point to the existence of marshes in many places. Continuous deposition did not prevail over the submerged area during the entire time; erosion by means of which some of the earlier Patuxent deposits were destroyed is shown in a number of instances. The occurrence of clay balls of Patuxent age within the Patuxent sand beds along the James River has already been noted. During the Patuxent submergence the region was probably beneath the water for some distance to the west of where we find the most westerly deposits now, but these deposits must have been very thin and they have since been removed by erosion.

The deposition of the Patuxent formation was ended by an uplift which brought the region above the water and inaugurated an erosion period which persisted long enough to permit the removal of a vast amount of material. This was followed by a subsidence in which many of the stream valleys but lately eroded were occupied for a portion of their courses by bogs and swamps. In these marshes there was an extensive development of plant life, and in them also were deposited the iron ores which in Maryland have been so extensively worked since Colonial days. These deposits constitute the Arundel formation.

After another elevation and erosion interval the land was again depressed beneath estuarine waters. Deposits similar to those which had formed during the Patuxent submergence were laid down throughout the northern Atlantic Coastal Plain. In Maryland these are very well exposed but in Virginia they appear at the surface chiefly along the Potomac River. They constitute the Patapsco formation. The greater abundance of red clay found in the Patapsco indicates that the source of some of the streams was in a region where the decomposition of the igneous rocks and the oxidation of the residual material had been going on for a long time. A marked change in the flora as compared with that of Patuxent and Arundel time indicates that a considerable period probably elapsed before the deposition of the Patapsco formation.

Following the deposition of the Patapsco formation the region again became land through an upward movement which drained all of the previously existing estuaries and marshes. Erosion at once became active and the Patapsco surface was dissected.

Late Cretaceous history.—A very long period of erosion apparently elapsed before the deposition of the Upper Cretaceous formations in Virginia. The land barrier that had kept out the ocean waters during the Potomac epoch had been broken down. The streams from the low-lying land evidently carried to the ocean at this time only small amounts of fine sand and mud which afforded conditions favorable to the production of glauconite and permitted the accumulation of the greensand beds which are so characteristic of the Upper Cretaceous formations along the Atlantic

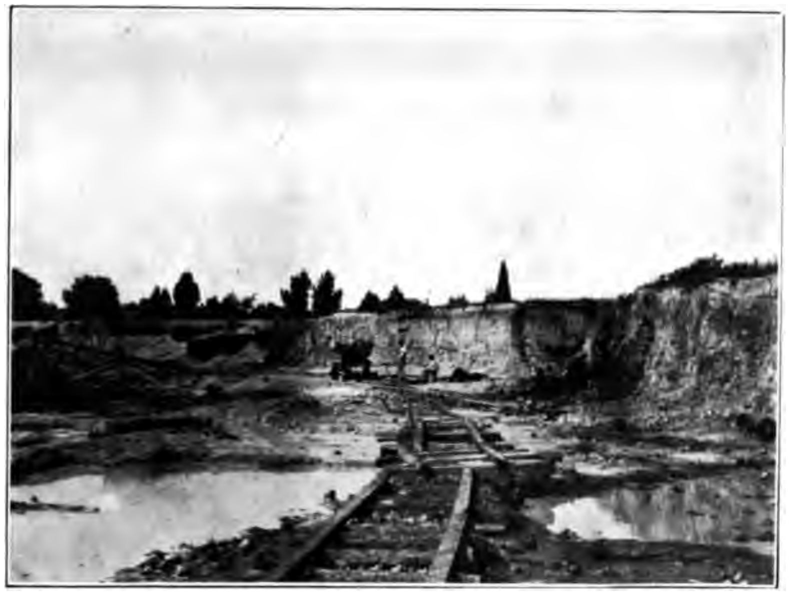

Fig. 1.—General view of Turner's clay pit, Ettricks, near Petersburg.

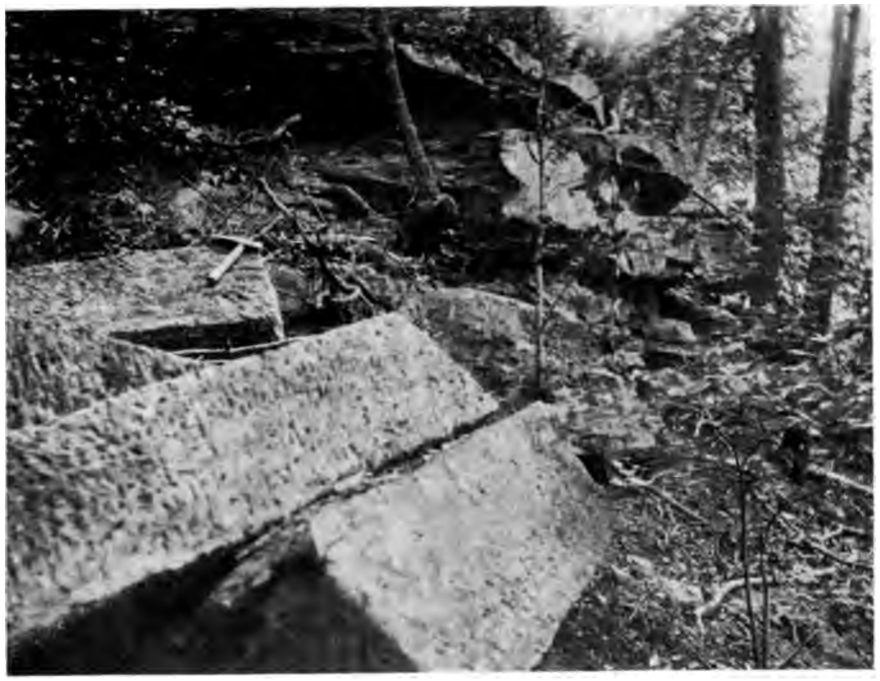

Fig. 2.—View of sandstone blocks in old quarry at Coles Landing, Aquia Creek.

CLAY PIT AND SANDSTONE BLOCKS.

coast. The shore-line during the Upper Cretaceous evidently lay farther to the east in Virginia than it had during the Potomac period. As has been stated before, the Upper Cretaceous deposits do not outcrop in Virginia but have been penetrated by the deep-well borings at Fairport and in the vicinity of Norfolk.

Eocene history.—In early Tertiary time a depression carried most of the region again beneath the waters of the ocean and the Eocene deposits were formed. The great amount of glauconite present in these formations indicates that the adjacent landmass must have been low and flat so that the streams carried only small amounts of terrigenous materials. The water in which these were deposited was doubtless not deep, as glauconite is not known to be produced at great depths. The land-derived material at the beginning of the Eocene consisted of coarse sand and occasionally small, well-rounded pebbles. Later the material brought in by the streams was much finer and consisted of fine sand or clay. Many forms of animal life characteristic of the infralittoral zone existed in these waters and their remains are now found composing layers of marl frequently many feet in thickness.

Studies of the fossils found in the Eocene deposits indicate that there were many changes in the fauna during this time. These changes were probably influenced to a greater or less extent by variations in the physical environment, yet the character of the deposits themselves gives little evidence of such changes. Instead, it seems probable that the conditions under which the Eocene deposits were produced were remarkably uniform, considering the great length of time which elapsed from the beginning to the close of the period.

Miocene history.—Eocene sedimentation was brought to a close by an uplift in which the shore-line was carried far to the eastward, and probably all of the present State of Virginia became land. This was followed by submergence, and another cycle was begun. The deposits of the Calvert were now laid down upon the eroded land surface of the Nanjemoy. Sluggish streams carried in fine sand and mud which they gave to the waves and ocean currents to spread over the sea bottom. The shore-line in the northern part of the Coastal Plain of Virginia was not quite as far west as it had been during the Eocene submergence. In the central and southern portions, however, it was farther west than it had been at any previous time since the beginning of Coastal Plain deposition. Thus we find in northern Virginia the Calvert beds resting upon the Nanjemoy, in the James River basin upon the Aquia, while somewhat farther to the south they are found in immediate contact with the crystalline rocks of the Piedmont. Near the shore leaves from land plants carried out to sea by the streams were dropped and their remains have been preserved in the fine-grained deposits of the Calvert in the vicinity of Richmond.

Near the beginning of the Miocene submergence certain portions of the sea bottom received little or no material from the land, and the water in those places was well suited as a habitat for diatoms. These must have lived in the waters in countless millions, and as they died their silicious shells fell to the bottom and produced the diatomaceous or infusorial earth beds which are so common in the lower part of the Calvert formation. Many protozoa as well as higher forms of animal life, particularly mollusca, lived in the same waters, and their remains are found plentifully distributed throughout the beds. At certain times conditions must have been especially favorable for animal life, as may be inferred from the great shell marl deposits which are found in so many places throughout Virginia.

After the deposition of the Calvert formation the region was again raised and subjected to erosion for a short period, and on sinking once more beneath the sea, the Choptank formation, which has been differentiated north of the Potomac River, was laid down contemporaneously with the advancing ocean. The Choptank formation lies unconformably on the Calvert in Maryland and farther north transgresses it and rests upon the Cretaceous deposits. During this last submergence conditions changed somewhat so that materials of different lithologic character were brought in. The sands of the Choptank in turn gave place to clay deposits alternating with layers of sand. These latter constitute the St. Mary's formation which in Virginia unconformably overlies the Calvert formation. These changes in physical conditions of sedimentation were accompanied by slight changes in the climate, which reacted upon the life forms inhabiting the ocean waters. Consequently we find in the St. Mary's formation a somewhat different assemblage of fossil forms. In general these are closely related to forms which now exist in somewhat higher latitudes. They indicate a slightly colder climate than had existed during the formation of the Choptank strata.

After the deposition of the St. Mary's an uplift brought practically the entire Coastal Plain of the State above the water, and a short period of erosion was inaugurated. The Yorktown period of submergence followed. During this period the ocean shore-line extended across the eastern part of the Coastal Plain, the Eastern Shore of Chesapeake Bay and the counties bordering Chesapeake Bay along the Western Shore were alone submerged. Molluscan life was very abundant during this time, and along the low, sandy beaches great accumulations of fragmental shell deposits were formed. These constitute the shell beds so well exposed in the cliffs at Yorktown. All during the Miocene there had been a gradual change in marine life, and in this latest period the forms were more closely related to the present fauna than those that lived earlier.

Pliocene history.—During the earlier Tertiary periods the adjacent land of the Piedmont Plateau had been subjected to erosion. The low character of the country prevented the weathered products of the Piedmont from being carried off by the sluggish streams. In late Pliocene time a subsidence occurred which brought the entire Coastal Plain and the margin of the Piedmont Plateau beneath the water. This was the greatest submergence that had occurred since the close of the Lower Cretaceous and perhaps was even more extensive than that during the Patuxent epoch. Coincident with the subsidence there seems to have been a slight elevation and tilting of the region west of the shore-line. The heads of the streams were given renewed force, enabling them to carry down and deposit over this region large quantities of gravel and sand derived from the Piedmont and Appalachian rocks to the westward. The evidence for the source of this material is found in the many different pebbles which, by their lithological character or the fossils which they contain, can be traced to their origin. In the vicinity of Washington and Richmond gravels are found containing fossils of Devonian and Carboniferous age, brought from beyond the Blue Ridge. These show that the Potomac and James rivers had extended their drainage basins far to the west. During the submergence of the region beneath the Lafayette sea conditions were not uniform over the entire area, as we have gravel deposits forming in some places at the same time that other beds were being deposited in adjoining regions, yet on the whole, sedimentation was remarkably uniform over the entire area, considering the circumstances under which it took place. Over the former land surface a persistent cap of gravel was deposited. Toward the close of Lafayette submergence the land slowly rose, and the velocity of the streams was so changed that gravel could no longer be carried down except in occasional freshets. Fine sand and loams were laid down over the gravel which had been previously deposited. This loam, which is so extensively developed over a large part of the region occupied by the Lafayette deposits, apparently marks the end of Pliocene sedimentation. It marks also the last time that the entire Coastal Plain of Virginia has been beneath the ocean waters.

Pleistocene history.—At the close of the Pliocene epoch the region was raised again and extensively eroded. It appears that after the close of the post-Lafayette erosion the Coastal Plain was gradually lowered beneath the waves and the Sunderland sea advanced over the sinking region. The Sunderland submergence was not as great in extent as the Lafayette submergence and a portion of the Coastal Plain remained above water. The waves of the Sunderland sea cut a scarp line against the existing headlands of the Lafayette and older rocks. These scarp lines are prominent in some places and obscure in others, for the reason that sea cliffs were not always cut as the ocean was bordered in some places by sandy beaches, while in other places the low cliffs cut in the unconsolidated sediments have now been entirely worn away. The waves supplied the materials, the undertow and shore current swept it out and deposited it; the basal member of the Sunderland formation, a mixture of clay, sands and gravel, representing the work of currents along the advancing margin of the Sunderland sea. The upper member of clay and loam was deposited on the other hand in deeper water after the shore-line had advanced farther westward as only the finer materials could be carried into the deeper waters. Ice-borne boulders are also found scattered through the formation at all horizons. These were carried by the ice that floated down the principal streams. The cold climate which prevailed during the Sunderland period seems to indicate the contemporaneity of the Sunderland period with the glacial epoch. It has, however, thus far not been possible to correlate the different periods of ice advance with the several Pleistocene formations of the Atlantic Coastal Plain.

After the deposition of the Sunderland formation the country was again elevated above ocean water, and erosion began to tear away the Sunderland terrace. This elevation, however, was not of long duration, and the country eventually sank below the waves again. At this time the Wicomico sea repeated the work which had been done by the Sunderland sea, depositing its materials at a lower level and cutting its scarp line in the Sunderland formation. At this time there was also a contribution of ice-borne boulders which were deposited miscellaneously over the bottom of the Wicomico sea, although more numerous in the vicinity of the larger streams. These are now frequently found imbedded even in the finer material of the Wicomico formation.

At the close of Wicomico time the country was again elevated and eroded and then lowered to receive the deposits of the Talbot sea. The geological activities of Talbot time were a repetition of those enacted during the Sunderland and Wicomico epochs. The Talbot sea usually cut its scarp line in the Wicomico formation but at times transgressed the latter completely and cut into the Sunderland or the underlying Cretaceous or Tertiary beds. Its terrace was deposited as a flat bench at the base of this escarpment. Ice-borne boulders are also extremely common in the Talbot formation, showing that blocks of ice charged with detritus from the land, were carried down by the major streams and deposited their load over the bottom of the Talbot sea as the ice melted, in precisely the same manner as during the Wicomico and Sunderland epochs.

Imbedded in the Talbot formation in several places are deposits of dark-colored clay filled with plant remains. The most important one occurs on the Rappahannock River a short distance above Tappahannock. The stratigraphic relation of this and similar lenses of clay occurring elsewhere in the Coastal Plain shows them invariably unconformable on the underlying beds and apparently so with the overlying sands and loams, although all form a part of the Talbot formation. Although the clay lenses seem to represent erosion unconformities, they do not, however, represent an appreciable lapse of time. The clays carrying plant remains are regarded as the lagoon deposits made in ponded areas and gradually buried beneath the advancing beach of the Talbot sea. In these ponds or marshes cypress trees and many marsh plants grew in abundance and their remains now form the vegetable débris found in the clay lenses. As the Talbot sea continued to advance, these marshes were finally covered with deeper water, and deposits of sand and loam continuous with the strata elsewhere were laid down, the line of separation appearing as a line of unconformity.

Recent history.—At the present time the waves of the Atlantic Ocean, of Chesapeake Bay, and of the other large estuaries are at work tearing away the land along their margins and depositing it on a subaqueous platform or terrace. This terrace is everywhere present in a more or less perfect state of development and closely resembles the earlier terraces. The materials which compose it are variable, depending both on the detritus directly carried down from the land to the sea and on the currents which sweep along the shore. On an unbroken coast the material has a local character while in the vicinity of river mouths the terrace is composed of débris contributed by the entire river basin.

Beside building a terrace the waves of the Atlantic Ocean and of Chesapeake Bay and its tributaries are cutting sea cliffs more or less pronounced along their coasts. The height of these cliffs depends not so much on the force of the breakers as on the relief of the land against which the waves beat. A low coast line yields a low sea cliff and a high coast line a high one. The one passes into the other as often and as suddenly as the topography changes so that as one sails along the shore of the Bay or estuaries high cliffs and low depressions are passed in succession. The wave-built terrace and the wave-cut cliff are constant companions along the entire extent of the bodies of tidal water.

In addition to these features, bars and spits are frequently noticed. If the present coast line were elevated slightly, the subaqueous platform which is now building would appear as a well-defined terrace of variable width with a surface either flat or gently sloping toward the deeper channels. This surface would everywhere fringe the Atlantic and Bay shores, as well as those of the estuaries. The sea cliff would at first be sharp and easily distinguished but with the lapse of time the less conspicuous portion would gradually yield to the leveling influences of erosion and might finally disappear altogether. Erosion would also destroy in a large measure the continuity of the terrace but as long as portions of it remained intact the old surface could be reconstructed and the history of its origin determined.

PHYSIOGRAPHIC RECORD

The history of the development of the topography as it exists to-day is not a complicated one. It has been formed at several different periods during all of which the conditions must have been quite similar. It is merely the history of the development of the four plains already described as occupying different levels and of the present drainage channels. The plains of the Virginia Coastal Plain are all plains of deposition which have been more or less modified by the agencies of erosion. Their formation and subsequent elevation to the height at which they are now found indicate merely successive periods of uplift and depression. The drainage channels have throughout most of their courses undergone many changes. Periods of cutting have been followed by periods of filling and the present valleys and basins are the results of these opposing forces.

Lafayette stage.—Within the borders of the Coastal Plain there is evidence of frequent changes during Mesozoic and early Tertiary time which resulted in the deposition of a succession of formations of varying materials. These, however, have been only to a very slight extent influential in producing the present topography. Many of the larger streams evidently occupied their present channels in the Piedmont Plateau during these periods, but their lower courses through the Coastal Plain were obliterated. Even in the early Cretaceous we find that the Coastal Plain deposits formed near the present stream courses consist of much coarser materials that the deposits formed over the divides. In the discussion of the physiographic history of the region as shown by the present topography, the changes which occurred during these periods may be omitted. Towards the close of the Tertiary, however, a change in conditions occurred which is clearly shown in the existing topography. A layer of gravels, sands, and clays was spread over the entire Coastal Plain and on the borders of the Piedmont Plateau during the Lafayette submergence. These deposits must have been laid down on a rather irregular surface, resulting in a comparatively thin mantle of materials 25 to 30 feet in thickness. When the uplift had terminated Lafayette deposition, a very even, gently sloping plain extending from the Piedmont Plateau to the ocean, bordered the continent. Across this plain composed of coarse and fine unconsolidated materials, streams having their sources in the Piedmont Plateau, gradually extended their courses, while new ones entirely confined to the Coastal Plain were also developed. At this time the shore-line seems to have been farther to the east, and the present submerged channels of the continental shelf were probably eroded during this interval. The Coastal Plain portion of the Delaware River with its extension as Delaware Bay; the Chesapeake Bay and the tidal portions of the Potomac, Rappahannock, York, James, as well as many smaller streams date from this post-Lafayette uplift. The attitude of the subsequent deposits makes this evident, for the Sunderland, Wicomico, Talbot, and Recent terrace formations surround, and in all cases slope toward these various water ways. The Lafayette formation was cut through in most places by the streams, and valleys were opened up in the older deposits, several of which became many miles wide before the corrasive power of the streams was checked by the Sunderland submergence.

Sunderland stage.—As the Coastal Plain was depressed during the early Pleistocene, the ocean waters gradually extended up the river valleys and then over the lower-lying portions of the stream divides. The waves working on the Lafayette-covered divides, removed the mantle of loose materials and either deposited the débris farther out in the ocean or dropped it in the estuaries produced by the drowning of the lower courses of the streams. Sea cliffs produced on points exposed to wave action were gradually pushed back as long as the sea continued to advance. These now represent the escarpments separating the Sunderland from the Lafayette. The materials which the waves gathered from the shore, together with other materials brought in by the streams, were spread out in estuaries and form the Sunderland formation. The tendency was to destroy all irregularities produced during the post-Lafayette erosion interval. In many places undoubtedly old stream courses were obliterated but the channels of the larger streams, while in some cases entirely filled, were in the main left lower than the surrounding regions. Thus in the uplift following Sunderland deposition the larger streams practically reoccupied the same channels they had carved out in the preceding erosion period. They at once began to clear their channels and to widen their valleys so that when the next submergence occurred the streams were cutting as before in Tertiary and Cretaceous materials. On the divides, also, the Sunderland was gradually undermined and worn back.

Wicomico stage.—After the Coastal Plain had been above water for a considerable interval a gradual submergence again occurred permitting the ocean waters to encroach on the land. This submergence seems to have been about equal throughout the Coastal Plain. The sea did not advance upon the land as far as it had during the previous submergence. The waves beat against the shores and in many places cut cliffs in the deposits that had been laid down during the former period and occasionally removed the entire width of the Sunderland terrace. Throughout many portions of the Coastal Plain at the present time these old sea cliffs are still preserved as escarpments, frequently 10 to 15 feet in height and occasionally much higher. During this time perhaps about one-half of the Coastal Plain of Virginia was submerged. The Sunderland deposits were largely destroyed by the advancing waves and redeposited over the floor of the Wicomico sea. Those portions of the Sunderland lying above 90 to 100 feet were not submerged and for the most part were not destroyed. Deposition of materials brought in by the streams from the adjoining land also took place.

During the Wicomico submergence deposition was effective in destroying a great many of the irregularities which had previously existed as shown by the great depth of the deposits formed in the erosion depressions. Many of the submerged stream channels were entirely silted up, yet the deposits were seldom thick enough to fill entirely the channels and valleys of the larger streams. Accordingly in the uplift following Wicomico deposition, the major streams reoccupied their former channels with perhaps only slight changes. New streams were also developed and the Wicomico plain was more or less dissected along the stream courses, the divides being at the same time gradually narrowed. This erosion period was terminated by the Talbot submergence which carried part of the land beneath the sea and again drowned the lower courses of the streams.

Talbot stage.—Talbot deposition did not take place over as extensive an area as had that of the Wicomico. It was confined to the old valleys and to the low stream divides where the advancing waves destroyed the Wicomico deposits. The sea cliffs were pushed back as far as the waves advanced and now standing as escarpments mark the boundaries of the Talbot sea and the Talbot estuaries. This is the Talbot-Wicomico escarpment previously described. In some places the deposits were so thick in the old stream channels that the streams in succeeding period of elevation and erosion found it easier to excavate new courses. Generally, however, the main streams reoccupied their former channels and renewed their corrasive work which had been interrupted by the Talbot submergence. The Talbot plain has now in many places been rendered quite uneven by recent erosion yet it is less irregular than the remnants of the Lafayette, Sunderland, and Wicomico plains which have been subjected to denudation for a much longer period of time.

Recent stage.—The land probably did not remain stationary with respect to the sea level long before another downward movement was inaugurated. This last submergence is probably still in progress. Before this subsidence occurred probably most of the important rivers, like the Potomac, Rappahannock, and James, were streams of varying importance lying above tide and emptying into the diminished Chesapeake Bay. Whether this downward movement will continue much longer cannot of of course be decided but there is evidence in many places throughout the Coastal Plain to show that this movement has been in progress within very recent time and in all probability still continues. Many square miles that had been land before this subsidence commenced are now beneath the waters of the Chesapeake Bay and its estuaries and are receiving deposits of mud and sand from the adjoining land.

ECONOMIC PRODUCTS OF THE VIRGINIA COASTAL PLAIN

BY

THOMAS LEONARD WATSON.

INTRODUCTION.

There occur within the Coastal Plain region of Virginia, numerous deposits of very considerable economic value. Some of these have been and are still being utilized, while others have scarcely commenced to be developed as yet. Not in a single instance, however, is the production of those products which have been utilized in any wise commensurate with the possibilities. The deposits of clay, sand and gravel, diatomaceous earth, calcareous (shell) and greensand marls, are very extensive and are generally of good grade. The extensive deposits of calcareous (shell) marl and clay, located directly on deep tidewater, offer large possibilities in the location of plants for the manufacture of Portland cement. The potentialities of the economic aspects of the geology of the Virginia Coastal Plain cannot be discussed at length in this chapter, but they are briefly summarized in the discussion that follows below.

DISCUSSION OF INDIVIDUAL PRODUCTS.

The more important of the economic products occurring in the Virginia Coastal Plain region are clays, sand and gravel, diatomaceous earth, greensand marl, calcareous (shell) marl, mineral paint, iron ore, building stone, peat, soils, and underground waters. These are discussed below in the order named.

CLAYS.

Clays have wide distribution over the Virginia Coastal Plain region. They are sedimentary clays, and are usually of unconsolidated character. Almost every formation in the region contains deposits of clay which are suitable for the manufacture of common brick, while the others are adapted to the higher grades of building brick, drain tile, hollow ware, and the cheaper grades of pottery.

The principal clay-bearing formations in the Virginia Coastal Plain are the Nanjemoy, Calvert, Lafayette, Sunderland, Wicomico, and Talbot. The Nanjemoy contains the compact pink or white clays previously described as occurring in the vicinity of Fredericksburg, and in the region south of Stafford Courthouse, where they form promising outcrops, but have not yet been developed. The Calvert contains a great deal of sandy blue clay which is found covering an extensive area in the western portion of the Coastal Plain. These clays are best known south of Richmond, in the vicinity of Curle's Neck, and Bermuda Hundred. This same formation also carries extensive beds of diatomaceous earth or clay, which is well exposed at Richmond and along the Rappahannock River.

The surface loams of the Lafayette, Sunderland, Wicomico, and Talbot formations have also been used largely in various parts of Tidewater Virginia about Alexandria, Fredericksburg, Petersburg, Emporia, Suffolk, Norfolk, Hampton, etc. Lying at the surface they can easily be worked as it is only necessary to remove a few inches of the soil. Sometimes this clay loam is used when only a little more than a foot in thickness but usually beds of not less than three or four feet in thickness are worked. At times the beds attain considerable thickness, as for example near the reservoir west of Richmond where the Lafayette clay loam is about 18 feet thick. More or less gravel and boulders occur distributed through the loams either in the form of isolated pebbles or as lenses or definite layers. These clays, Pleistocene chiefly, occur as more or less basin-shaped deposits widely scattered over the Coastal Plain region.

Nearly all of the clay deposits noted in the Coastal Plain region, whatever their geological age, are of lenticular or lens-shaped character. The majority of them are red-burning, while only a few are buff-burning. No white-burning clays have thus far been found, but even though they lack in variety, so far as their color-burning qualities are concerned, it is probable that their possible uses are more numerous than is now supposed.

The amount of clay suitable for the manufacture of common brick throughout the Coastal Plain is almost unlimited, and the distribution of the deposits is such that brick sufficient for local consumption can be made in almost every neighborhood. It is difficult to understand why these clay deposits have not been more extensively utilized hitherto. Practically no attempt has been made to use the higher grade clays at any point.

The results of a study of the Virginia Coastal Plain clays, including physical tests and chemical analyses, by Dr. Heinrich Ries in 1905, are embodied in the table opposite page 225.

IN

Laboratory No.	Color	LOCALITY	Per ct. water required for mixing	Con	
					Color
1300	Yel. buff	Brick mixture, Maynard & Powers, Richmond	20.9	Mo	br'
1302	Yel. buff	Fort Lee	24.2	Mo	red
1305	Gray blk.	Two miles south of Chester	25.3	Fas	red
1306	Yel. buff	One mile northwest of Bermuda Hundred	29.7	Fas	ay
1307	Yel. buff	Keeler's yard, Broadway, on Appomattox River	24.6	Slo	d gr
1311	Yel. buff	Sturgeon Point	23.1	Mo	red
1312	Gray	Oldfield	20.3	Slo	ay
1313	Buff	Oldfield	23.1	Mo	gr
1314	Yel. buff	Ball property six miles southeast of Richmond	20.9	Mo	r.br
1315	Yel. buff		23.1	Mo	ay
1316	Lt. gray		24.2	Mo	ab
1322	Br. buff	Impure diatomaceous earth Richmond	31.6	Fas	d gr
1323	Buff		34.6	Fas	d gr
1324	Yel. buff	W. J. Ready's yard, Manchester, by Richmond	20.3	Mo	red
1325	Brown		20.3	Mo	red
1326	Br. buff		18.7	Fas	d
1330	Gray	Williamsburg road, near Stagg's Mill, Richmond	27.8	Slo	ay
1331	Br. buff	Turner's yard, near Petersburg	23.1	Slo	red
1333	Lt. brown	Wood's yard, near Emporia	24.0	Slo	red
1334	Lt. brown	Clays showing variable character of upper bed at Sturgeon Point	24.2	Mo	r.gr
1335	Gray		18.7	Fas	red
1336	Gray		18.7	Fas	lt.r
1336a	Gray	Clay from river level, Sturgeon Point	30.2	Mo	red
1339	Br. buff	City Point	20.3	Slo	red
1343	Gray	Standard Brick Co., south of Suffolk	22.	Slo	yell
1344	Drab	Blue clay, Suffolk Clay Co., Suffolk	31.9	Slo	gra
1345	Buff	Brick mixture, Suffolk Clay Co., Suffolk	26.4	Slo	ay
1350	Pink	Eocene clays from between Stafford C. H. and Fredericksburg	36.3	Mo	br'
1352	White		35.2	Mo	bu
1353	Yel. br'n	Between Milford and Bowling Green	27.5	Mo	br'
1354	Gr'n gray	One mile south of Layton	24.2	Slo	br'n
1356	Light red	Red clay, northwest of Fredericksburg	33.0	Fa	red
1358	Light red	Diatomaceous earth, one mile south of Layton	23.1	Fa	br'n
1362	Lt. brown	Pleistocene clay, Wilmont	19.2	Mo	red
1363	White	Diatom earth, Wilmont	62.4	Fa	low
1365	Buff	Clay from "House" bank southeast of Wilmont	22.0	Mo	yel
1367	White	Sandy clay, Occupacia P. O.	26.4	Fa	br'

*FeO, 1 per cent.

s.s. Slightly swelled.

The chemical analyses in this table were made by Messrs. J.

OF MICH.

5	Cone 8			Chemical Composition											
% Absorption	Fire shrinkage	Color	% Absorption	Loss on Ignition	Silica, SiO_2	Titanium Oxide TiO_2	Ferric Oxide Fe_2O_3	Alumina, Al_2O_3	Lime, CaO	Magnesia, MgO	Potash, K_2O	Soda, Na_2O	Total Fluxes	Laboratory No.
1.4	6.3	Red br'n	1.29	4.61	71.50	1.44	4.78	13.86	.56	.11	2.29	0.81	8.50	1300
2.6	7.3	Deep br.	1.10	5.52	69.55	1.06	6.05	15.79	Tr'ce	.08	1.54	0.38	8.05	1302
Fus'd	.0	----------	-----	4.41	69.74	.06	6. *	12.64	1.46	1.18	2.54	0.92	13.15	1305
2.11	6.6	Dk. red	1.39	5.32	61.83	.08	6.85	21.26	.38	.78	2.44	1.01	11.46	1306
1.7	7.6	Red br'n	.50	6.67	59.59	.12	8.07	21.10	.20	.76	2.38	1.06	12.47	1307
1.5	5.6	Dk. red	1.07	4.53	68.60	.16	6.41	16.11	.75	.32	2.35	.71	10.54	1311
1.08	7.3	Drab	1.57	2.81	73.84	1.22	3.39	15.08	.62	.12	2.17	.71	7.01	1312
1.68	5.	Drab	1.10	5.34	68.97	1.28	4.22	16.51	.44	.05	2.59	.56	7.86	1313
2.6	s.s.	Dk. red	1.02	4.10	65.97	1.04	6.74	17.38	1.16	.17	2.46	.93	11.46	1314
.7	7.	Red br'n	.55	5.41	63.82	Tr'ce	6.32	20.44	.22	.11	2.72	.93	10.30	1315
.14	s.s.	Drab	.90	4.82	66.01	.50	3.59	20.77	.92	.11	2.52	.74	7.88	1316
5.06	2.	Brown	2.04	5.21	70.42	.44	5.17	15.15	.14	.79	2.24	.39	8.73	1322
1.70	5.6	Red gray	1.09	6.39	63.17	.88	6.32	19.30	.06	.69	2.45	.69	10.21	1323
1.4	5.5	Dr.r.br'n	.19	4.03	73.38	N'ne	5.53	13.53	.58	.14	2.32	.47	9.04	1324
6.29	Vis.	Red br'n	1.47	4.85	69.43	N'ne	6.70	14.79	.57	.63	2.26	.71	10.87	1325
1.6	.6	Red br'n	1.00	3.65	72.61	.44	5.61	13.08	.96	.23	2.45	.93	10.18	1326
2.4	3.	Drab	1.56	5.29	63.06	.04	6.26	20.90	.16	.45	3.13	.68	10.68	1330
3.	6.3	Dk. red	1.30	7.25	61.35	.06	7.10	19.70	.67	.34	2.38	1.11	11.60	1331
6.20	6.	Dk. red	1.08	6.09	67.14	N'ne	6.21	16.18	1.19	.11	1.95	1.10	10.56	1333
5.	5.	Red br'n	.21	5.07	69.75	.06	4.67	17.13	.53	.31	1.89	.56	7.96	1334
7.86	3.6	Lt. br'n	.31	3.03	74.55	.22	3.07	15.43	.43	.65	1.42	1.16	6.73	1335
10.91	1.3	Lt. br'n	6.50	3.24	77.78	.20	3.05	12.84	.40	.29	1.69	.44	5.87	1336
.15	7.	Dk. red	.04	7.49	61.21	Tr'ce	5.81	20.82	.57	.75	2.57	.73	10.43	1336 a
1.3	6.6	Dk. red	1.52	7.76	61.06	.16	7.03	19.61	.77	.09	2.34	1.01	11.24	1339
7.01	3.3	Lt. br'n	3.60	5.06	75.79	Tr'ce	3.17	14.85	.04	.08	.75	.22	4.26	1343
Bey'nd vitri	.0	Drab	-----	6.66	64.39	.08	4.40	20.49	.17	.91	2.31	.54	8.33	1344
.60	5.	Red drab	.02	5.98	65.55	1.95	5.29	18.13	.39	.51	1.82	.33	8.34	1345
3.50	10.3	Red br'n	3.74	8.63	51.12	.47	10.70	26.14	.10	.25	1.78	.77	12.87	1350
8.30	10.	Drab	2.49	8.44	57.26	.14	3.10	28.97	.04	.19	1.40	.42	5.15	1352
2.09	5.	Red br'n	2.02	5.09	69.00	.10	6.72	15.58	.06	.15	2.34	.91	10.18	1353
27.9	2.3	Red	24.79	3.55	85.72	.06	1.74	5.83	1.01	.11	1.31	.64	4.81	1354
.18	13.3	Dk. red	.02	6.00	55.33	.81	9.02	25.69	.22	.08	2.57	.25	12.14	1356
5.4	6.3	Lt. br'n	2.57	3.66	78.82	.33	5.42	9.24	.04	.12	1.51	.81	7.90	1358
5.9	4.3	Br. red	2.03	4.74	71.60	1.88	4.65	13.18	.42	.66	1.58	1.23	8.54	1362
38.3	5.6	Yel. br'n	32.32	3.40	82.85	1.09	2.34	6.76	.35	1.06	1.07	.99	5.81	1363
11.2	2.3	Red yel.	9.87	4.59	77.28	.06	2.42	13.01	N'ne	.70	1.22	.68	5.02	1365
21.05	5.	Brown	19.	3.06	84.64	.24	2.59	7.73	.10	.17	1.12	.32	4.30	1367

DESCRIPTION OF CLAY AREAS.[a]

The Alexandria Area and Vicinity.

This area is the most important brick-making district in the Virginia Coastal Plain region. It cannot be said that this marked local expansion of the clay-working industry is due to the more abundant occurrence of clay at this point, but rather to the fact of its nearness to an active and important market, namely, the city of Washington. Nearly all the brick yards of this area are situated so close to the city, that the product is hauled across the river by teams, and the daily continuous procession of wagons loaded with brick indicates the demand for the Virginia product.

The clays used in the Alexandria district are the Columbia loams, which underlie the low hills around Alexandria, Arlington, Addison, Riverside, etc. They are all sandy loams of variable color, yellow, red, brown, and bluish-gray, and are frequently of a mottled character. Most of the clays burn to a red brick, but certain ones show a tendency to fire buff, and since these lighter burning parts are oftentimes tougher, they do not mix readily with the red-burning clay when the run of the bank is used, so that the buff spots show in the brick after burning. At the yard of the Washington Hydraulic Pressed Brick Company, the several clays are carefully separated and burned alone, thus giving several different shades of product.

The firms in operation in this region are: Washington Hydraulic Pressed Brick Company; Jackson-Phillips Company; Potomac Brick Company; Virginia Brick Company; Estate of Charles Ford; Walter Brick Company; West Brothers; Alexandria Brick Company; Washington Brick and Terra Cotta Company; and American Hygienic Brick and Tile Company. The last is located near Riverside.

The Fredericksburg Area.

The most prominent clays in the region around Fredericksburg are those belonging to the Eocene formation. While these no doubt underlie a considerable area between Fredericksburg and Stafford to the north, still prominent outcrops of them are not very abundant.

The nearest of these to Fredericksburg is located along the road from Fredericksburg to the Cartwright and Davis granite quarry on the hill leading up from the canal. This material, which is of a bright red color, is known, locally, as paint clay, and is said to have been used by the Indians for that purpose. How extensive the bed is can only be determined by boring, for no outcrops of it are seen, except along the road, but there it is exposed in the ditch at the roadside for several hundred feet at least. Tests of this clay (No. 1356) are given in the appended table, facing page 225.

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[a] Abstracted from chapter on clays in Mineral Resources of Virginia, 1907.

Following the road from Fredericksburg to Stafford, there are a number of indications of bluish-white Eocene clay in the ditches along the roadside but most of these are topped by a heavy bed of sand. About 6 miles east of north from Fredericksburg, a heavy bed of the clay is found on top of a ridge.

The section here involves:

	Feet
Surface sand and soil	1-2
Pink clay, laminated	12
Whitish clay	4

The pink clay (Lab. No. 1350) is distinctly stratified and in its upper part contains some scattered crusts of limonite. The physical and chemical properties of this clay are given in the table opposite page 225.

The clay, although burning to a good color, is not a dense-burning one; in fact, it does not yield as tight a body as some of the Pleistocene clays. Its main use should be for common brick, pressed brick, or drain tile. The outcrop mentioned is somewhat distant from the railroad for cheap exploitation, but the extension of this bed should be found to the westward, nearer lines of transportation.

The whitish clay (Lab. No. 1352), which underlies the pink clay, is of buff-burning character and burns to a good body. It would no doubt make a good light-colored pressed brick by either the wet method repressed, or the dry-press process. Its analysis and physical tests are given in the table opposite page 225.

The Wilmont Area.

This is practically the only locality along the Rappahannock River where the Pleistocene clays are worked, and the quality of those developed at this point would make it seem desirable to prospect further for other deposits.

At the brick works at Wilmont the following section is exposed:

	Feet
Soil	1
Blue clay (so-called)	5-6
Gravelly sand (variable thickness)	6-15
Diatomaceous earth	10
Greensand clay	4

The blue clay, which is of Pleistocene age, is mixed with either the diatomaceous clay, or with clay from another surface deposit not far distant. The green sandy clay, which is the same as that tested from Layton, lies below the level of the yard.

Another deposit of Pleistocene clay, known as the House clay, is dug about one-fourth mile northeast of the brick works. Here the clay runs from 9 to 13 feet in thickness and is underlain by sand. Still another deposit has been located one-half mile northwest of the brick yard. Only the House clay (Lab. No. 1365) and that at the brick yard (Lab. No. 1362) were tested. Their properties are given in the table opposite page 225.

Although these clays are both surface clays, and occur in the same formation at no great distance from each other, still they are quite dissimilar in many respects.

No. 1362 is a red-burning clay which burns to a good bright color. Its air shrinkage is not excessive and its fire shrinkage is low. It contains some coarse grit which shows up clearly on the fractured surface of the burned bricklet. At cone 8 portions of the clay become viscous. This is not a fire clay, but it works well for brick and fireproofing.

No. 1365 is a gritty, light-burning clay which does not burn steel-hard until cone 5, and even at 8 still shows a rather high absorption. Its low air shrinkage and low tensile strength are characteristic of sandy clays. The material can be classed as a low-grade fire clay, such as is used in terra-cotta manufacture, or for boiler-setting brick. It is the most refractory of the series tested from the Coastal Plain area.

The brick works at Wilmont produce fireproofing, boiler-setting brick, and some front brick. In each case a mixture of the Pleistocene clays, or of these with diatomaceous earth, is used.

The Layton Area.

Along the shore of the Rappahannock River, about 1 mile south of Layton, there is a long outcrop of gritty greenish clay, of Miocene age, which is evidently part of a rather extensive deposit. The material is well shown in the river bluff, and its smooth vertical surface stands out in marked contrast to the overlying sand. The bed as here exposed is not less than 9 feet thick, and is overlain by 6 to 8 feet of sand, which may be adapted to molding purposes. The clay (Lab. No. 1354) in table opposite page 225, evidently underlies the diatomaceous earth which crops out farther down the river, and both are overlain by the sand referred to above. This same clay is seen inland from the river, behind the mill at Occupacia post-office; it also underlies the diatomaceous earth at Wilmont, and is seen at several other points along the river bank.

It is exceedingly sandy, as can be told by the feel, and seen from the analysis (silica, 85.72 per cent.). Its shrinkage is very low and it burns to a very porous body, so that it would seem undesirable to use it for even common brick.

Overlying this at Occupacia post-office is a whitish sandy clay (No. 1367) of table opposite page 225, which, although quite different in appearance from the green clay, resembles it closely in both physical and chemical properties. One might suppose, judging from its color, that it was a fire clay or at least semi-refractory in its character, but it is not.

The Milford Area.

Along the road from Milford to Bowling Green, and about three-quarters of a mile from the former locality, there is a promising deposit of yellowish brown Pleistocene clay, 10 to 12 feet thick. The bed is underlain by sand, but has very little overburden. Its characters are given in the table opposite page 225 (No. 1353).

This is a red-burning surface clay, which becomes steel-hard at 03, but is too gritty to use for any purpose except common-brick manufacture. It would probably work on a dry-press machine.

The Richmond Area.

Richmond, next to Alexandria, is the most important clay-working center in the Coastal Plain region, there being a number of yards engaged in the manufacture of common and in some cases pressed brick. Most of these are located on the edge of Richmond and in the suburbs of Manchester and Fulton, while a few are located near the reservoir and race track.

The output of these is not sufficient to supply the demand, and some outlying towns are also drawn upon. The better grades of pressed brick in Richmond are not made in the Coastal Plain area. Some are obtained from Clayville, Powhatan County, Virginia, but most of them come from points outside of the State.

There are four yards in operation in Manchester, all of them being located in the vicinity of Knight and Maury streets. All of these are engaged in the manufacture of soft-mud brick and a few of them also produce a small quantity of pressed brick. The clay used is a more or less mottled, gritty, yellow or reddish clay, which is covered by a thin layer of sandy soil and commonly underlain by a bed of sand. At only one point, namely, the yard of Green and Harrison, is the underlying crystalline rock encountered. The clays in general are very tough and plastic, sometimes quite sandy, and they contain a variable quantity of stony material which ranges in size from small pebbles up to large boulders, most of these being of crystalline character. This stony material is not found to be uniformly distributed through all the beds, but seems to run rather in streaks, the greatest quantity of it having been observed in the bank of W. J. Ready, and Green and Harrison.

At G. E. Redford's yard, the clay shows an average thickness of 12 feet with a maximum of 17 feet, and is underlain by a hard bed of sand and gravel. It is a mottled gritty clay with scattered mica fragments and many limonite stains running through it; and it contains also many decomposed pebbles of crystalline rock. The clay pit is a large shallow excavation lying to the south of the yard and the working face has a height of from 6 to 8 feet. The material is red-burning, and for the manufacture of bricks the run of the bank is commonly used. This is necessary because the clay seems to vary somewhat in its physical character. Thus, for instance, it is not safe to use that found in the north end of the pit alone, because it is very tough and cannot be used without cracking. It is mixed therefore with the more sandy portions of the bed.

Adjoining the yard of Redford on the west is that of W. B. Davis. This pit, which is a large shallow excavation, lies to the south of the yard, and has a working face of from 6 to 7 feet in height. The clay is similar to that in Redford's bank, but seems to contain fewer stones.

Adjoining Davis' yard on the east is that of W. J. Ready. The clay pit which lies to the northwest of the yard is much deeper than the neighboring excavations and also lies at a slightly lower level, for the upper surface of the clay is uneven and slopes towards the river. The clay in general is somewhat similar to that found at the two preceding yards but contains more stones and boulders than are found in either Redford's or Davis' bank. The thickness of the clay is said to be at least 18 feet, and it is probably underlain by sand. Here in a working face of perhaps 200 feet in length they recognize three different kinds of clay, only one of which they claim can be used alone. If either of the other two is used by itself, it results in an imperfect product. The physical and chemical characters of these three clays are given in the table opposite page 225.

A plant is also operated by W. J. Ready near the West End yard and is located a quarter of a mile west of the track near the reservoir. The material is the usual mottled surface clay which is worked to a depth of about 7 feet, although a total thickness of 20 feet is claimed for it.

The yard of the Fulton Brick Company, which is commonly spoken of as Westford's yard, is located west of the Chesapeake and Ohio Railway round house. The clay used here is the ordinary surface clay and does not seem to run over 10 feet in thickness. It also contains many cobble stones. Underlying this is a fine sand which is at least 8 feet deep and is used for sanding the brick molds.

The Baltimore Brick Company operates two yards at Rockett, a suburb of Richmond. The yards are located near the intersection of Ohio and Williamsburg avenues. The clay is tempered in ring pits, molded by hand, and burned in dutch kilns. Some 17 years ago the company tried making soft-mud machine brick but gave it up for some unknown reason. The clay is obtained from under the surface at several points in the vicinity of the yard and averages from 15 to 18 feet in thickness with an underbedding of sand. The material is quite similar in character to that at Manchester, but lacks the stones and boulders.

Maynard and Powers' pit is southeast of the Baltimore Brick Company's excavation. The working face is about 12 feet high and shows a sandy, mottled, yellowish-brown and gritty clay similar to that occurring in the other pits in this vicinity. The company claims that its clay runs 20 feet in depth and is underlain by a bluish-gray sand. The chemical and physical properties of this clay (No. 1300) are given in the table opposite page 225.

A clay very similar to that on the Ball property, 6 miles south of the city, and probably of the same age is also found outcropping on the Williamsburg road leading to Stagg's Mill, about one-half mile to the west of where the road crosses the railroad. The clay is exposed on a sloping hillside, and in such position that a large quantity can be removed without having to take off much overburden. It is also well located for shipment. As far as could be ascertained the bed is not less than 20 feet thick. It (Lab. No. 1330) is a grayish clay, which slakes slowly and works up with 27.8 per cent. water to a mass of high plasticity. Its air shrinkage, 12.6 per cent., is somewhat high; so also is the average tensile strength, namely, 300.9 pounds per square inch.

This is a very plastic clay which becomes steel-hard at cone 05. It gives a light red color up to cone 03, but at cone 1 gives an excellent dark red color. Its point of vitrification is apparently reached at about cone 3, and at cone 5 it was well passed vitrification and had swelled considerably. It is not as good a clay as that described from near Bermuda Hundred (Lab. No. 1317) or Curle's Neck (Lab. No. 1314).

The Fort Lee Area.

At Fort Lee on the Chesapeake and Ohio Railway, about 2 miles south of Richmond, there is a group of yards operated, respectively, by C. H. Oliver, J. M. Davis, and the Fulton Brick Company. The general run of the clays is not unlike those used around Richmond, but none of the pits show stony material, such as is found in some of the Richmond clay banks.

The most southern of this group of yards is that of C. H. Oliver, which is located one mile west of Fort Lee. The clay is found immediately underlying the surface and the bank shows 12 feet of clay, although the total thickness of it is said to be 20 feet. Underlying it is a pit of gravel and sand of unknown depth. For making bricks the run of the bank is used. The general physical properties of this clay (No. 1302) are given on page 225.

Adjoining Mr. Oliver's yard on the west is that of J. M. Davis. The clay used is similar to that employed at Oliver's pit described above. It is molded by hand, dried on pallets, and burned in dutch kilns. A few hundred feet up the track and on the north side of it are two yards operated by the Fulton Brick Company. The brick yard adjoins the clay bank on the west and the material is practically the same as that seen at the Davis place, but the methods used for winning the clay are more improved.

The dark-colored clays, similar to those described from south Chester, outcrop at several points around the base of Government Hill, especially along the Government road leading down from the top of the hill, but in nearly every instance they are covered with too much overburden to permit of their being profitably worked.

Summary.—It may be well to make a comparative summary of the clays found in the Richmond area. Those found near the city, and those which are worked at Manchester, Fulton, and near the reservoir, are to be classed as good common-brick clays, which burn to a good color, and also make a fair grade of front brick when repressed. They are too gritty and stony as well as too irregular in their character to be used for drain tile, hollow blocks, or red earthenware. The methods used for working them are usually crude, and therefore the yards are of limited capacity. The manufacturers claim, however, that owing to difficulties with labor, it is impracticable to use more improved methods, such as machine molding. Some also maintain that the hand-molded brick sell better on the local market.

The clays found at Fort Lee appear to be less stony and even less sandy than those occurring at Richmond, and they are susceptible of being worked by more improved methods. Of the yards located at Fort Lee, one used a soft-mud machine, and another a stiff-mud machine. Even these clays, however, are somewhat siliceous for any use other than brick, although it is probable that drain tile or hollow brick could be made from them.

Apparently the best clay in the Richmond area is that described from near Stagg's Mill on the Williamsburg road. This is more plastic, denser burning and less sandy, than any of the clays now being worked either around Richmond or Fort Lee. The deposit being located so close to the city, as well as close to a railroad line, should be investigated by clay manufacturers.

Large areas have already been dug over in the brick-making districts around Richmond, because the deposits are comparatively shallow, and the output of the yards has been large. Each manufacturer naturally excavates the clay nearest to his yard first, so that as year after year goes by the pit face recedes, and the clay haul becomes longer and longer. As the city of Richmond and its suburbs are growing, it will not be many years before building will encroach on the brick yards, and the latter will have to be moved. Being, as it were, temporarily located, there is therefore not much inducement for establishing an extensive plant.

The Curle's Neck Area.

About one mile north of Curle's Neck and 6 miles south of Richmond, there are a number of exposures of clay along the road, and also on the farm on the west side of the road, at a locality pointed out by Mr. W. A. Ball, of Richmond. This material has been usually spoken of as fullers earth, and some sample car-loads have been shipped to cotton oil factories in order to test it for bleaching purposes. The material, however, is very plastic and on inspection one would be likely to form the opinion that it was a clay suitable for the manufacture of some red-burning ware. In fact it is stated that at one time a small stoneware pottery was in operation at this point and there is considerable evidence of this in the numerous fragments of stoneware which are scattered over the field near the farmhouse. Three samples, Nos. 1314, 1315, and 1316 were tested from this locality, the results being given in the table opposite page 225.

The Chester Area.

A number of outcrops of clay are seen in the railroad and trolley road cuts in the vicinity of Chester. None of them, however, are suited to the manufacture of brick. About two miles south of Chester along the Atlantic Coast-Line Railway there are several cuts, which show outcrops of a sandy, bluish fossiliferous clay. The material is not uniform in character, certain layers being highly fossiliferous, others very sandy, and still others very plastic. The exact thickness of the deposit is not known, but from the exposures, it is evidently not less than 30 feet thick. No attempts have been made to use it.

The general characteristics of the clay may be summed up as follows: Red burning, low fire shrinkage, and low fusibility. Difficult to burn. It is not to be recommended for anything but common brick, and even for this purpose it should be avoided if something better can be found.

The Bermuda Hundred Area.

Much clay is exposed at a point along the railroad from Chester to Bermuda Hundred and about 1 mile from the railroad station at the latter locality. The same material is also seen in the gullies in the neighboring fields. This clay is at the same level as that which is worked at Broadway, on the Appomattox River, and it is probable that the deposit extends in that direction, but it does not belong to the same formation.

The exposures in the railroad cut show a thickness of not less than 10 feet, and a thickness of 49 feet was proved by boring in one place. Although the clay along the railroad track does not show much variation on inspection, it is stated that at the northeastern end it is brick clay, while at the southeastern end it is tile clay. The properties of the brick clay (No. 1306) are given in the table opposite page 225.

Judging from the dense body of this material it would be worth experimenting with for paving brick, or perhaps pipe. The most serious objection to it is its high air and fire shrinkage.

This clay has been dug and shipped occasionally to the works of the Powhatan Clay Manufacturing Company, at Clayville, near Richmond.

The Petersburg Area.

There are several yards in operation near Petersburg. Two of these, the W. R. Turner, and Brister and Harrison, are located in Ettricks, across the river from Petersburg; the third, that of the Chesterfield Brick Company, is situated about two miles from Petersburg near the line of the Petersburg-Richmond trolley road. They all make an excellent grade of red brick. The properties of these clays are given in the appended table opposite page 225.

The clay is molded on a plunger stiff-mud machine, dried on pallets, and burned in scove kilns. The local contractors state that the supply of bricks from the yards around Petersburg is entirely sufficient to meet the demand in that city.

The Broadway Area.

The only brick yard in operation at this locality is that of Keeler and Son, which is located immediately at the foot of the bluff along the Appomattox River. The clay deposit lies about 75 feet above the river and the clay is being dug at a point in the terrace about 300 feet south of the yard. It is a tough, mottled material with a thickness of at least 15 feet, the upper 2 feet of which are weathered. Overlying this are about 18 inches of gravelly sand similar to that which occurs immediately under the surface throughout this region, on both sides of the river. The clay is underlain by a coarse, gravelly sand which extends down to the river level and probably below it.

The clay burns steel-hard at cone 05 and at either this temperature or cone 03 it makes an excellent red brick. If burned to this cone, or better still, to cone 1, the material would probably make a good pressed brick.

This is an excellent red-burning clay which could probably be used for making front as well as common brick, provided it is thoroughly pugged. At the present time it is utilized for making common brick, and the run of the bank is used, leaving out the overburden of gravelly sand.

The City Point Area.

The Pleistocene clays outcrop in the bluff along the James River, about one-eighth mile south of City Point landing. Their distribution is evidently irregular, for in the first cut of the railroad after leaving City Point, there is nothing but sand exposed, although the bottom of the cut is not as high as the upper part of the clay along the river shore. I was informed that borings made to the south of the railroad cut had revealed the presence of the clay under the surface sand. Along the shore the clay is not less than 20 feet thick, but it contains occasional streaks of sand. There are also about 4 feet of sand overburden. No brickyard is located at this point although the deposit is at the water's edge and the product could be easily shipped. Occasional car-load lots have, however, been dug and shipped to the smoking pipe factory at Pamplin City. As for this line of ware, a small quantity of clay will go a long way, so that the amount that has been dug has produced little impression.

The characters of the clay (No. 1339) are given in the table opposite page 225. Its chief advantage is convenient location for shipment by rail, an advantage not possessed by most deposits along the James River.

The Sturgeon Point Area.

The W. C. Mayo and Sons brick plant is located along the river's edge at the base of the bluff, while the clay is obtained from near the top of the bluff. The section at this point involves:

	Feet
Loam	1 to 2
Clay	7 to 8
Sand	2
Mottled clay with iron streaks	9
Sand	20 to 30
Blue sand	3+

The sand mentioned in the lower part of the section extends down to the river's edge, and at that point it is underlain by a bed of dark bluish-gray, highly plastic clay, which is about 3 feet in thickness. The upper layer of clay was formerly worked and a considerable quantity of it has been dug. The clay was found, however, to be so variable in character and burning qualities that it was undesirable for use, consequently the raw material for the yard is taken from the middle clay bed given in the section, which yields a more uniform product.

It is claimed that this deposit of clay extends more or less continuously for at least twelve miles back from the river.

The Oldfield Area.

This locality lies about four miles south of Sturgeon Point and on the same side of the river. The Oldfield Brick and Tile Company is engaged in the manufacture of common brick. The clay here, as at Sturgeon Point, underlies the terrace which borders the river, and the brick yard is located at the base of the terrace escarpment on the river's edge. It may be said that the materials underlying the terrace consist of dense or alternating beds of sand and clay overburden, and an upper bed of loamy clay underlain by a siliceous clay, which weathers to a whitish color and contains many cylindrical limonite concretions. The upper bed has an average thickness of about 3 feet, and this is first removed and utilized for the manufacture of common brick. The under bed seems to vary in thickness, but where best exposed at the south side of the deposit and nearest to the yard, the thickness is at least 7 feet. It is underlain by a tough sandy clay which is not used and which passes downward into a bed of loamy sand containing streaks of pebbles. The two kinds of clay are worked separately, the upper clay being used for common brick, and the lower clay, with the limonite concretions, known as the tile clay, being used for tile or extra hard brick, termed paving brick. A sample of each of these was tested and the tests given in the table opposite page 225.

The Belfield Area.

This town, which adjoins the better known one of Emporia, has one yard, whose product consists entirely of common brick, and which is operated by Dr. Wood, of Emporia. The soil is quite sandy around Belfield, and the surface flat, so that there are very few clay exposures. At the brick yard the clay extends nearly to the surface and averages about 5 feet deep, being bottomed on a coarse, whitish sand, which is not mixed in with the clay, as it does not seem to improve its quality. The clay burns to an excellent red color and makes a good common brick.

The Norfolk Area and Vicinity.

The cities of Norfolk, Portsmouth, and Newport News, are among the most important in the Coastal Plain area of Virginia, and in all, building operations are being carried on quite extensively. There is here consequently a good market for building brick, either common or pressed, and the supply is drawn from a number of points.

There are several yards in the immediate vicinity of these cities which deserve mention. E. W. Face and Son operate a yard on North Avenue, Atlantic City. The raw material is brought from a pit of Pleistocene clay on the Nansemond River, near Suffolk, and in its general character resembles that worked at the brick yards around Suffolk. It is a red-burning clay of excellent plasticity, which yields a good product for structural work. Before molding, the clay has a small quantity of fine coal mixed in with it, to help in burning, a practice somewhat unusual in the Coastal Plain area. It is molded on an end-cut auger machine, dried on hot floors, and burned in up-draft kilns with permanent side walls.

The plant of the Builders Supply Company is located on Middle Street, Chesterfield Heights. The clay is a light-colored sandy material averaging about 3.5 feet in thickness. There are only a few inches of soil over it, and the clay is free from stones or shells.

G. A. Stephens' brick yard is located on the Princess Anne road near Godfrey Avenue. It is also working surface clay, which, however, is somewhat different in its appearance from that at the preceding plant. The clay which immediately underlies the soil is a bluish-black, very stiff red-burning clay.

C. H. Phillips and Brothers operate a yard at Hampton, near Newport News, and a reddish, sandy, surface clay is used, for making common soft-mud brick.

At Morrison, 1 mile north of the station, is the yard of the Booker Brick Company, whose product goes mostly to Norfolk. This is a shallow Pleistocene deposit, 3 to 4 feet in depth and underlain by sand. The material is red-burning and used only for the manufacture of common brick.

The Suffolk Area.

Four brick yards were visited at this locality, namely, those of the Standard Brick Company, Horrell and Company, Suffolk Clay Company, and West End Company.

The Standard Brick Company's yard is located about one mile and a half south of Suffolk along the Southern Railway. The surrounding region is underlain by a deposit of sand, often of coarse grain and variable thickness. Some of it might serve for molding sand, and much of it no doubt would answer for the manufacture of sand-lime brick. At the pit of the Standard Brick Company, some stripping is necessary before the clay is reached. The bed has a depth of about 6 feet, the lower two or three feet being a dark bluish-gray and the upper half discolored by weathering. The lower clay gives a harder brick but has a higher shrinkage than the top clay.

The yards of the Suffolk Clay Company, and the West End Company, are located west of Suffolk and on adjoining properties; in fact, the clay deposits worked at the two are probably continuous at the yard of the West End Company. The clay deposit varies from 5 to 15 feet in thickness with very little overburden. It is underlain by a bed of black sand, which in places is quite clayey, but is not dug with the brick clay. The clay has been traced horizontally for at least 200 yards, and contains few stones. No sample of this was tested. The clay is worked up in a stiff-mud machine, and dried in twenty-four hours in steam-heated tunnels.

At the bank of the Suffolk Clay Company, the section shows:

	Feet
Top soil	1
Yellow clay	3
Blue clay, lower foot sandy	9
Limonite sand	1
Sand	8
Blue marl	20

For brick making the run of the bank, including the sand layer, is used. The blue clay is not safe to use alone by any process of wet-molding, but it gives a harder, denser body. The properties of the brick mixture (No. 1345) and the blue clay (No. 1344) are given in the table, opposite page 225.

The following table gives the statistics of clay products in the Virginia Coastal Plain from 1905 to 1909 inclusive, and is of interest to those who desire to know something of the growth of the industry in the eastern part of the State.

Clay products in Virginia Coastal Plain from 1905 to 1909, inclusive.[a]

Year.	No. of Producers.	No. of Counties Producing.	Value.
1905	43	16[a]	$1,485,227
1906	40	14[b]	1,424,220
1907	39	16[c]	1,098,998
1908	39	15[d]	1,199,533
1909	42	17[e]	1,473,728

[a] Includes Alexandria, Charles City, Chesterfield, Elizabeth City, Fairfax, Greenesville, Henrico, James City, King George, Lancaster, Nansemond, Norfolk, Prince George, Princess Anne, Spottsylvania, and Warwick counties.

[b] Includes Isle of Wight County, and the counties under (a) except Greenesville, Princess Anne, and Spottsylvania.

[c] Includes Isle of Wight and Sussex counties, and the counties under (a) except King George, and Spottsylvania.

[d] Includes Caroline, Isle of Wight, and Sussex counties, and the counties under (a) except Elizabeth City, Greenesville, and King George.

[e] Includes Isle of Wight and Sussex counties, and the counties under (a) except Caroline and Elizabeth City.

Of the 17 counties producing in 1909, Alexandria, Henrico, Chesterfield, and Nansemond, in the order named, were the largest producers. During 1909, there were 9 producers in Alexandria County, 7 in Henrico, 6 in

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[a] Furnished by the courtesy of the Division of Mineral Resources, U. S. Geol. Survey.

Chesterfield, and 5 in Nansemond. The total production of these 4 counties amounted to $1,219,090 or 82.72 per cent. of the total production for the entire Coastal Plain region.

SAND AND GRAVEL.

Sand and gravel are found in almost every one of the Coastal Plain formations. The sands of the Virginia Coastal Plain region are employed as building sand, molding sand, engine sand, and in the manufacture of sand-lime brick. Gravel and sand are also used for road-building.

Sand.—Sand, both coarse and fine, is found in almost every one of the Coastal Plain formations. At times the sand consists of pure quartz grains, but at other times is mixed with more or less clay or gravel and occasionally, particularly in the Potomac deposits, arkose forms the matrix for the sand grains. These are sometimes covered with a ferruginous coating which tends to bind the grains together. Ferruginous sands pack together much better than the pure quartz sands and hence afford much finer roads where they form the surface materials. The very sandy roads common in the eastern part of the State are caused by the absence of binding material to hold the solid grains together.

The better grades of sand have been locally used in great quantities for building purposes. Some of the sands are probably pure enough to be utilized as glass sands although none have been employed for that purpose hitherto. In New Jersey some of the Miocene quartz sands have been used in the manufacture of glass, and doubtless the same formations in Virginia contain equally desirable materials for glass-making.

Molding sand has been obtained from several pits along Gillis Creek in the southeastern part of Richmond, and is of very good quality. Most of it is used in Richmond although some has been shipped elsewhere. This sand belongs to the Aquia formation and contains considerable glauconite, a constituent of all the Eocene sands. The deposit is of a pepper and salt color with certain portions stained brown by the iron oxide produced in the decomposition of the glauconite. There are at times small pebbles in the sand while certain beds contain casts of fossils. Sand with apparently similar characteristics is found throughout the Aquia formation, so that it is probable that much material suitable for molding purposes can be obtained from this formation throughout the Virginia Coastal Plain region. In Maryland some of the slightly arkosic sands from the Potomac deposits have also been used as molding sands which suggests the probable occurrence of equally desirable sands in the same formation in Virginia.

During his investigations of the Virginia Coastal Plain clays in the summer of 1905, Dr. Heinrich Ries studied the molding sands in the vicinity of Richmond, Petersburg, and Fredericksburg. The samples of these sands collected by Ries were analyzed by Messrs. Eoff and Gibboney, with the results shown in the table which follows below.

Analyses of molding sands from the Virginia Coastal Plain region.

Constituents	I Per cent	II Per cent	III Per cent	IV Per cent	V Per cent	VI Per cent
Silica (SiO_2)	81.59	82.08	66.12	82.32	70.24	70.40
Alumina (Al_2O_3)	6.46	7.12	16.54	7.80	16.62	3.80
Iron oxide (Fe_2O_3).....	4.94	4.63	4.46	3.98	3.94	14.94
Lime (CaO)	0.14	0.36	0.40	0.54	0.08	0.12
Magnesia (MgO)	0.22	0.35	0.22	0.41	0.09	0.15
Potash (K_2O)	1.19	1.28	2.67	1.64	1.41	1.95
Soda (Na_2O)	0.59	0.41	0.35	0.80	0.74	0.41
Titanic oxide (TiO_2)...	1.90	0.30	0.14	0.22	0.46	0.70
Water (H_2O)	1.63	1.66	4.90	0.19	4.16	4.08
Water (moisture)	1.46	1.52	4.15	0.14	2.42	3.77
Total......	100.12	99.71	99.95	98.04	100.16	100.32

Constituents	VII Per cent	VIII Per cent	IX Per cent	X Per cent	XI Per cent
Silica (SiO_2)	84.40	93.92	85.04	86.24	89.39
Alumina (Al_2O_3)	7.56	3.22	5.90	6.32	5.94
Iron oxide (Fe_2O_3)..............	2.52	1.08	3.18	2.44	1.22
Lime (CaO)	0.06	0.24	0.06	0.34	0.32
Magnesia (MgO)	0.21	0.08	0.14	0.10	0.09
Potash (K_2O)	1.29	0.45	1.65	1.38	2.10
Soda (Na_2O)	0.65	0.23	0.83	1.13	0.53
Titanic oxide (TiO_2)............	0.44	0.32	0.78	0.02	0.18
Water (H_2O)	1.99	0.48	1.57	2.94	0.54
Water (moisture)	1.76	0.18	1.11	1.29	0.19
Total.......	100.88	100.20	100.26	102.20	100.50

I. Redford sand from foundry, Manchester, Virginia.
II. Redford yellow sand collected at pit, Manchester, Virginia.
III. Coarse sand, Harbaugh pit, Richmond, Virginia.
IV. Used molding sand, Redford pit Manchester, Virginia.
V. Sand from near Petersburg, Virginia.
VI. Blandford pit, Petersburg, Virginia.
VII. Armstrong pit, Petersburg, Virginia.
VIII. Sand from near Standard Brick Company, south of Suffolk, Virginia.
IX. Griffith's pit, Fredericksburg, Virginia.
X. Curlis pit, southeast of Lanexa, New Kent County, Virginia.
XI. One mile south of Layton, Essex County, Virginia.

The following physical tests made by Ries on the samples of sand from Virginia further serve to show their general character:

Locality	20	40	60	80	100	100X	Clay
Redford yellow sand collected at pit in Manchester	1.51	1.26	1.27	0.56	6.27	71.69	16.52
Coarse sand, Harbaugh pit, Richmond	42.48	12.90	6.16	0.85	1.70	8.58	26.44
Nsed molding sand, Redford pit, Richmond	5.34	14.73	10.41	1.28	14.61	59 37	3.52
Sand from near Petersburg..........	0.73	2.34	8.76	2.21	12.25	14.79	30.54
Blandford pit, Petersburg............	3.03	1.41	0.97	0.40	2.61	48.32	41.87
Armstrong pit, Petersburg	0.09	0.41	2.21	2.67	17.37	53.20	19.02
Sand from near Standard Brick Company, south of Suffolk.............	0.12	0.29	13.00	6.56	38.02	35.18	6.03
Griffith's pit, Fredericksburg	0.19	0.19	0.39	0.19	0.98	81.92	15.97
Curlis pit, southeast of Lanexa	.....	0.01	0.08	0.07	1.11	86.77	19.57
One mile south of Layton	6.68	28.13	51.66	3.18	3.75	2.63	2.16

Along the tide-water streams on the sandy beaches may be seen thin layers of heavy black sands, composed largely, if not entirely, of grains of magnetite. These beaches are sometimes covered to a depth of several inches with almost pure sands of this character, although usually the fine sandy beaches contain layers of black sands interbedded with fine yellow sands. In some places along the lower Rappahannock River it would be impossible to obtain sands of this character in considerable quantities. It is doubtful whether the sands will ever prove valuable as an iron ore but it is possible that other minerals of greater value may be present with the magnetite. Investigations recently carried on by the United States Geological Survey on the black sands of the Pacific Coast have revealed the presence of magnetite, ilmenite, chromite, zircon, and monazite, all of which have a commercial value in the arts. In some places such sands contain gold and platinum. Although the black magnetite sands of Virginia are probably of little value in comparison with the much more abundant deposits on the Pacific slope, it is desirable that their composition be determined.

Gravel.—The Lafayette, Sunderland, Wicomico, and Talbot formations furnish the principal gravel deposits of the Coastal Plain, although the Patuxent and Patapsco formations also contain locally considerable beds of gravel. The last two formations have a very limited outcrop in Virginia so that their economic importance as a source of gravel is not great. The other four formations, however, contain an abundance of gravel suitable for road-making, and their wide distribution renders them of particular value throughout the greater portion of the region. One or another of these formations is present almost everywhere in the Coastal Plain except on the steeper slopes, and even in such places the talus consists largely of Pleistocene or Lafayette débris. Generally a gravel band is found at the base of each of these formations, covered by a surface loam cap in which are distributed scattered pebbles or pebble lenses.

The Lafayette, in its most western limits, is almost entirely composed of the clay residuum of the crystalline rocks, and the Pleistocene deposits in the extreme eastern portion of the State are often composed almost entirely of fine sands but elsewhere these formations contain much gravel. The gravel is more abundant in proximity to the larger streams and decreases in amount and in size of the pebbles over the broader divides, yet removal of the upper clay loams at some distance from the main streams will usually reveal the presence of a gravel layer.

Gravel pits are numerous although much less use has been made of the deposits for road purposes than one would expect when it is everywhere recognized that the heavy sandy roads have been serious drawbacks to the development of the country in so many portions of the Virginia Coastal Plain. The gravel is of very unequal value for road-building purposes, depending primarily on the matrix in which the gravel occurs. Pure quartz gravel in a matrix of loose sand will not pack of itself and is of little value if spread on sandy roads. If spread over a clay road, however, it will become mixed with the clay and eventually form a firm road bed. In some places the gravel occurs in a clay or ferruginous sand matrix and is then splendidly adapted for road-building purposes. By making several applications of such gravels the worst highways can eventually be converted into firm roads both in dry and wet weather.

The table below shows the details of the sand and gravel industry of the Virginia Coastal Plain, and the comparative quantities and values in 1908 and 1909.

Production of Sand and Gravel in Virginia Coastal Plain, 1908 *and* 1909, *by uses, in short tons.*

	1908		1909	
Sand—	*Quantity*	*Value*	*Quantity*	*Value*
Glass	......	.....	....	....
Molding	41,900	$ 20,925	15,489	$ 12,605
Building	103,936	46,096	340,318	107,749
Fire	......	.....	....	....
Engine	......	.....	1,526	220
Furnace	2,960	2,554	1,379	1,881
Other	4,712	760	43,631	6,349
Gravel	234,894	24,154	319,487	69,631
Total	388,402	$94,489	721,830	$198,435

These figures do not represent the total production of sand and gravel in the Virginia Coastal Plain, as large quantities are produced and utilized each year in the manufacture of brick, and in railway, highway, and sidewalk construction, etc., of which no record of the quantity used is kept and no returns are made to the office of the State Survey. Much the largest proportion of sand used in the State, for which returns are made, is for building and molding.

DIATOMACEOUS EARTH.

Diatomaceous earth, known in the trade under the name of "silica," "infusorial earth," or "tripoli," is composed of the minute shells or tests of microscopic plants known as diatoms, and is widely distributed in the Calvert formation. It was first reported from the vicinity of Richmond, Virginia, and for that reason received the name of "Richmond earth," under which term it is sometimes referred to in the literature. Because of its occurrence at Bermuda Hundred on the James River, it has been called "Bermuda earth."

The first bed of diatomaceous earth of any extent discovered in this country was in the Richmond area. It is known as the Richmond bed, which extends from Herring Bay on the Chesapeake, Maryland, to Petersburg, Virginia, and probably beyond. It is not less than 30 feet in thickness in places, though very impure at times, grading frequently into layers of clay. It is of Miocene (Calvert) age, light brown and red to almost pure white in color, and is exposed along the numerous streams close to their crossings from the crystalline rocks on to the sediments of the Coastal Plain.

Specimens of the diatomaceous earth collected from various points in the Virginia Coastal Plain region gave the following results on analysis:

Analyses of Virginia Diatomaceous Earth.

Constituents	I[a]	II[a]	III[b]	IV[b]	V[b]	VI[b]
Silica, amorphous	65.83	51.67	63.17	70.42	78.82	82.85
Silica, crystalline........	14.65	23.56				
Alumina	4.17	10.25	19.30	15.15	9.24	9.76
Ferric oxide	2.34	2.79	6.32	5.17	5.42	2.34
Lime	trace	0.27	0.06	0.14	0.04	0.35
Magnesia	0.71	0.69	0.69	0.79	0.12	1.06
Titanic oxide	0.40	0.64	0.88	0.44	0.33	1.09
Soda	....	....	0.69	0.39	0.81	0.99
Potash	....	....	2.45	2.24	1.51	1.07
Ignition	11.63	10.18	6.39	5.21	3.66	3.40
Total.......	99.73	100.05	99.95	99.95	99.95	99.91

[a] Smither, F. W. Analyses of Infusorial Earth. Amer. Chem. Jour., 1897, Vol. XIX, pp. 235-236.

[b] Ries, Heinrich. A Preliminary Report on a Part of the Clays of Virginia. Bull. No. II, Geological Series, Virginia Department of Agriculture and Immigration and Virginia Polytechnic Institute, 1906, p. 143.

I. Diatomaceous earth from the northern bank of the Rappahannock River at Greenlaw's Wharf, King George County. F. W. Smither, analyst.

II. Diatomaceous earth from President's Hill, Richmond, Virginia. F. W. Smither, analyst.

III. Diatomaceous earth from 7th Street, near Richmond Locomotive Works, Richmond, Virginia. Eoff and Gibboney, analysts.

IV. Diatomaceous earth from same locality as III. Eoff and Gibboney, analysts.

V. Diatomaceous earth from the Rappahannock River south of Layton. Eoff and Gibboney, analysts.

VI. Diatomaceous earth from Wilmont on the Rappahannock River. Eoff and Gibboney, analysts.

It will be seen from examination of these analyses that the earths show much variation in their chemical composition. I, II, and III show low silica, and the first two are described as being unusually pure, as indicated by microscopic study. IV, V, and VI are quite siliceous and one of them highly so. These are shown from microscopic study to be less pure than I and II, and III and V are very impure.

The diatomaceous deposits around Richmond have long been known, and are referred to in many publications. The beds outcrop in great thickness in the embankments along the tracks at the Richmond Locomotive Works, and along the sides of the valley to the west. In general character the earth is a silty porous clay, which breaks out in irregular lumps. In places it is traversed by vertical fissures which are filled with limonite. Analyses II, III, and IV in the table above are of diatomaceous earth occurring around Richmond.

There are long exposures of diatomaceous earth along the Rappahannock River, especially in the vicinity of Layton and Wilmont. The diatomaceous earth beds have a thickness of about 50 feet and stand out in bold almost vertical cliffs, which when viewed at a distance present an appearance almost as white as chalk. These cliffs stand out prominently in the sunlight and can be seen for a long distance. This earth is apparently purer and lighter than much of that around Richmond, and like the latter it passes in places into clay. Analyses I, V, and VI in the table above are of diatomaceous earth occurring at Greenlaw's Wharf, King George County, and near Layton and Wilmont, Essex County, on the Rappahannock River. Other good exposures of the earth are at Carter's Wharf on the Rappahannock River, and along Shockoe Creek in the eastern part of Richmond with an indicated thickness of about 20 feet.

On account of its porosity and compactness diatomaceous earth is used in water filters and as an absorbent of nitroglycerine in the manufacture of dynamite. It is reduced readily to a fine powder, the hardness of the individual particles and their sharp edges making it an excellent base for polishing compounds. Its low heat conductivity makes it a valuable ingredient in the manufacture of packing for steam boilers and pipes, and in the construction of fire-proof safes. It has been frequently utilized for the latter purpose. It has also been suggested that it might be used in certain branches of pottery manufacture, which require on the part of the materials both refractoriness and an absence of color when burned.

In 1905, samples of diatomaceous earth were collected around Richmond and the Rappahannock River, and tested by Dr. Heinrich Ries. The results of the chemical analyses are given in the table above, and those of the physical tests on page 246.

Physical Tests made of Virginia Diatomaceous Earth.

Laboratory Number.	III (1322)	IV (1323)	V (1358)	VI (1363)
Color, moist	Brown buff	Buff	Light yellow	White
Water required	31.6	34.6	23.1	62.4
Slaking	Fast	Fast	Fast	Fast
Plasticity	Lean	Lean	Low	Low
Grit	Some	Some	Little	Some
Air shrinkage	13	14	10.3	3.6
Average tensile strength	.....	.....	29.4	34.4
Cone 010				
Fire shrinkage	0.6	0.6	0.6	1.3
Color	Light red	Light red	Light red	Yellowish
Absorption	14.62	14.9	21.73	50.96
Cone 05				
Fire shrinkage	0.6	2.3	0.6	1.6
Color	Light	Light	Light	Light pink
Absorption	13.6	10.9	20.70	48.4
Cone 03				
Fire shrinkage	2	3.3	2.3	1
Color	Light red	Light red	Light red	Pink
Absorption	12.42	9.0	15.88	44.70
Cone 1				
Fire shrinkage	3	5	5.6	4.6
Color	Light brown	Medium red	Pink	Pink cream
Absorption	9.1	4.16	11.3	41.4
Cone 3				
Fire shrinkage	3.3	6	5.6	4.6
Color	Red brown	Medium red	Red gray	Yellow
Absorption	6.9	2.30	9.5	40.9
Cone 5				
Fire shrinkage	5	6	6	5.3
Color	Red gray	Red gray	Light brown	Yellow
Absorption	5.06	1.70	5.4	38.3
Cone 8				
Fire shrinkage	2	5.5	6.3	5.6
Color	Brown	Red gray	Light brown	Yellow brown
Absorption	2.04	1.08	2.57	32.32

III. (No. 1322). Weathered diatomaceous earth from 7th Street, near Richmond Locomotive Works, Richmond. This, after burning, closely resembles the diatomaceous earth near Layton along the Rappahannock River. It seems to be vitrified at cone 5, and at cone 8 is viscous.

IV. (No. 1323). This sample was collected from the same locality as No. 1322, but at greater depth below the surface. It is quite impure, and shows a high air shrinkage. It burns red and becomes steel-hard at cone 05. It is vitrified at cone 5, and nearly viscous at cone 8.

V. (No. 1358). Diatomaceous earth along the Rappahannock River south of Layton. This burns fairly dense at the higher cones, and gives a clean color, but is quite porous at the lower cones.

VI. (No. 1363). Diatomaceous earth from Wilmont. This burns to a very porous body as is indicated by the absorption figures. It has a low air and fire shrinkage.

Though occurring in the Coastal Plain region in great abundance, the deposits of diatomaceous earth are worked at present only to a very limited extent. At Wilmont some of this material is mixed with Pleistocene clay and used in the manufacture of brick. A few years ago it was quarried and shipped from a point on the Rappahannock River a short distance below Wilmont but the plant has now been abandoned. According to the United States Census office, the output of diatomaceous earth in Virginia in 1902 was limited to the production of two concerns. There has been no reported production of diatomaceous earth in Virginia for several years.

GREENSAND MARL.

The Eocene and locally the Miocene deposits of Virginia contain considerable glauconite, a dark green mineral which is essentially a hydrous silicate of iron and potash. The glauconite occurs in the form of small grains, varying in amount from very nearly pure beds of that substance to deposits in which the arenaceous and argillaceous elements predominate. At certain places the shells of organisms are found commingled with the glauconitic materials in such numbers as largely to make up the beds, producing what is known as a greensand marl. Such a marl contains two of the most important constituents to plant growth, potash and lime, while most analyses show a small percentage of phosphate of lime even more beneficial as a plant food. It is for these reasons that the greensand or glauconitic marls have long been known to be of value as natural fertilizers. The marl improves both the chemical and physical condition of the soil. It is very lasting in its results, the effects being noticeable for many years, but its bulkiness will probably always prevent it being extensively used in its natural condition except locally. From 60 to 100 bushels per acre should be used on sandy soils and from 160 to 200 bushels on clay soils.

Greensand deposits of Upper Cretaceous age have been worked for more than 100 years in New Jersey and almost invariably the users report increased soil fertility. Similar deposits of Tertiary age have been worked in Delaware, Maryland, and Virginia but to a less extent. To obtain the best results the marl should be dug and allowed to weather for a few months in order to permit all the firmer masses to disintegrate, after which it is spread over the surface of the ground in a thin layer.

Besides serving as a natural fertilizer, greensand marl is now frequently used as a base in the manufacture of artificial fertilizers. For this purpose the greensand is dried, pulverized and then shipped to the fertilizer plants. Most of the greensand marl now dug in New Jersey and Virginia is being used in this way.

The distribution of greensand marl in Virginia is almost coextensive with the distribution of the Aquia and Nanjemoy formations, as both of these contain a great deal of glauconitic sand. The region along the Pamunkey River is underlain by valuable deposits and more has been dug there than at any other locality in the State. Similar material outcrops along the Potomac and the Rappahannock rivers and their tributaries in Stafford, King George, and Caroline counties and along the James River and its tributaries in Henrico, Charles City, and Prince George counties. Extensive beds of greensand marl occur in portions of James City, York, Hanover, Chesterfield, Prince William, and Spottsylvania counties. The beds vary greatly in depth and in the amount of potash and phosphoric acid contained. Potash varies according to the proportion of the mineral glauconite present, ranging usually from one per cent in the very impure greensands to 8 and 10 per cent in the purer greensands. Shells are usually present in the deposits and supply lime in addition to potash and phosphoric acid.

Greensand marls have been dug at a number of places on the James and Pamunkey rivers. The most important place for the production of marl within recent years is on the James River in Prince George County a few miles below City Point. The marl was there dug, dried and shipped. Some Miocene shell marl was also ground up with the greensand marl.

The following analyses, made of greensand marls collected from Hanover, Suffolk, and Prince George counties, Virginia, and Aquia Creek, Stafford County, Virginia, serve to show their composition:

Analyses of Virginia Greensand Marl.

	Major Winston[1] Hanover County		Aquia Creek[2] Stafford County	Waverly[3] Sussex County	City Point[3] Prince George County	
	Per cent	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
				Insol.		
SiO_2 combined.....	47.45	43.34	.....	.....	.....	.....
SiO_2 uncombined ..	2.76	8.22	21.58	45.20	61.15	56.03
Al_2O_3	7.33	6.62	7.70	.....	.....	.....
Fe_2O_3	12.03	15.16	.....	.....	.....	.....
FeO	9.43	8.33	.....	.....	.....	.....
MgO	2.90	0.95	1.05	5.22	2.19	0.37
CaO	0.57	0.62	36.78	24.38	1.36	1.52
K_2O	5.75	4.15	0.37	4.73	3.85	3.15
Na_2O	0.42	1.84	0.59	.....	.....	.....
P_2O_5	.....	.....	0.09	1.80	0.47	0.05
H_2O	9.85	10.32	0.76 (at 110°)	.....	.....	.....
CO_2	.....	.....	29.79	.....	.....	.....
Volatile at red heat less CO_2........	.....	.....	0.21	.....	.....	.....
Total.........	98.49	99.55	98.92			
Siliceous matter...			25.36			

[1] Corse, M. B. and Baskerville, Chas. Analyses of Glauconite from Hanover County, Virginia. Amer. Chem. Jour., 1892, Vol. XIV, p. 627.

[2] Analysis by Peter Fireman of Columbia University.

[3] Ellett, W. B., and Eskridge, A. T. Virginia Experiment Station Bulletin.

CALCAREOUS (SHELL) MARL.

The various Miocene formations of Virginia, especially the Yorktown, contain extensive deposits of molluscan shells, and frequent fish and mammalian bones. The marl beds usually attain considerable thickness as well as lateral extent, and the percentage of lime in them is very high. Analyses of the marls generally show a small amount of potash and phosphoric acid. The percentage of lime in the beds depends largely upon the amount of sand and clay present, forming the matrix of the beds, as the shells are composed almost entirely of calcium carbonate. Some of the marls contain as much as 97 per cent of calcareous matter. The bones yield most of the potash and phosphatic material present, some of the Miocene bones containing as much as 30 per cent of phosphoric acid. The calcareous or shell marls owe their principal value, however, to the lime content.

The large areal extent and high lime content of the Virginia Miocene shell marl beds render them of great commercial value for use (a) in agriculture, and (b) in the manufacture of Portland cement. These two principal uses of the Virginia shell marls are discussed separately in the order named.

Use in Agriculture.—As a fertilizer lime has wide application on acid soils or those deficient in lime. Lime has been used to some extent as a fertilizer for many years, but it is only within recent years that considerable scientific attention has been directed to its use. Many of the state agricultural experiment stations have investigated the use of lime as a fertilizer.

The effect of lime upon soils is three-fold: (1) It produces important chemical changes; (2) it changes the physical properties of soils which are deficient in calcium; and (3) it serves as a plant food as it is an essential constituent of many plants.

Chemically lime tends to break up many refractory minerals whose elements reunite to form other compounds which are soluble and can serve as plant foods. It replaces potash in certain of the silicates, liberating that element in such form that it may be used directly by the plant. If the soil contains much humus or vegetable matter the lime will promote its decomposition, resulting in liberating nitrogen in the form of ammonia which is a valuable plant food. Heavy and continuous liming may be carried to such an excess that the plant food will be liberated more rapidly than the plants can make use of it. Because of its alkaline nature, one of the most important functions performed by lime when applied to acid soils is the neutralizing of acidity.

Physically lime ameliorates the texture of the soil. Clay soils which have a tendency to cake upon drying are rendered more open and porous in texture by liming, while loose sandy soils may be rendered more compact and retentive of moisture by liming.

Professor H. J. Patterson[1] states that "most cultivated soils possess a slightly acid reaction. This is generally due to the decomposition of the remains of plants in the soil forming organic acids. On wet soils this condition is more noticeable than on dry soils. The sour humus and organic acids are not only unfavorable to the growth of nitrifying ferments and the root tubercles of leguminous plants, but also are likely to dissolve iron and other compounds which are poisonous to crops. Water-culture experiments have shown that slightly acid solutions are favorable to the growth of plants, and while most soils possess this character to slight degree, yet any excess of soluble acid in the soil would be highly detrimental. While most of our cultivated crops seem to need a slight acidity, it is probable that they have the ability to create this condition to a sufficient degree through the medium of the solutions sent out by their roots. This being the case, it would seem that the aim should be to keep soils in a neutral or slightly alkaline condition, so as to favor the growth of root tubercles of the legumens and the desirable soil ferments. Liming is excellent for correcting any excess of acidity, and is probably the most effective and economical substance for bringing about these other desirable conditions." It is a well-recognized fact that sheep-sorrel thrives in an acid soil where grass and grain will scarcely grow at all. In such places the application of lime or marl destroys the soil acidity with the resultant destruction of the sheep-sorrel and renders possible the growth of profitable crops.

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[1] Maryland Agriculture Experiment Station Bulletin 66, p. 97.

"The many chemical changes brought about by the action of lime on soils result in producing physical changes which give soils new mechanical characteristics. Lime has the power of changing the physical properties of a clay soil and making it more friable and easily cultivated, and putting it in a condition so that water may pass more freely through it. This will make it less susceptible to extremes of dry and wet weather, and make it a good home for the roots of the plants. The action of lime on sandy soils may be said to be the reverse of that on clay soils; that is it has a cementing action, making such soils stick together in such a condition that they will hold more water and not dry out so rapidly."

Shell marl is somewhat less valuable than commercial lime, because of its slower action, yet all the advantages claimed for lime as a fertilizer may be equally well claimed for the natural marl. In many places throughout Tidewater Virginia shell marl has been extensively used and, except when put on in too large quantities, has materially increased soil fertility and proved a valuable stimulus to plant growth. In many places, however, since the Civil War very little marl has been used, notwithstanding the fact that much excellent marl is locally available. In some places the fossil shells have been burned for lime, which is spread over the surface. In this form the lime becomes effective almost immediately, which is often very desirable. Where the shells are very well preserved and compact, the action of the natural shell marl is very slow, some shells remaining in the soils for a great many years almost unchanged.

Generally the marls made up of the shells of *Ostrea, Pecten, Venus,* and *Crassatellites* are poor fertilizers on account of the slowness with which they decompose, while the gastropod shell marls are much better on account of their more friable texture and more rapid decomposition. The *Chama* marls are especially desirable. Shell marl has been dug in past years at numerous places in the Virginia Coastal Plain, and used extensively on the land, but little has been dug in recent years.

Use in Portland cement manufacture.—Only within the past several years has serious attention been drawn to the shell (calcareous) marls of the Coastal Plain as raw material for use in mixing in the manufacture of Portland cement. Investigations conducted by the State Geological Survey show that extensive deposits of shell marls of good grade and suitable for the making of Portland cement occur in many places in the Virginia Coastal Plain. The most favorable deposits are of Miocene age, the areal distribution of which is shown on the accompanying map, Plate I. Of the Miocene formations, the Yorktown is one of the most fossiliferous represented in the series of Atlantic Coastal sediments. It has a thickness in Virginia of approximately 125 feet and contains a very rich and varied fauna. The formation outcrops in Gloucester, James City, York, Warwick, Isle of Wight, and Nansemond counties.

In their natural state, some of the marls contain too large a percentage of sand to be used directly in cement making, but must be treated by a simple process before mixing in order to reduce the sand content, which proportionately increases the calcareous matter. Associated with the marls in many places are beds of clay of sufficient thickness and quality as to render them suitable to mix with the calcareous marl for Portland cement manufacture.

Recently, three plants of large capacity have been granted charters for the manufacture of Portland cement in the Coastal Plain (Tidewater) region of Virginia. These are the Norfolk Portland Cement Corporation's plant located near Norfolk, the Jamestown Portland Cement Corporation's plant to be located at Yorktown, and the Colonial Portland Cement Corporation's plant to be located at the Grove, 7 miles east of Williamsburg. Of these, the plant of the Norfolk Portland Cement Corporation has been completed and is producing. The raw materials to be used by these plants in the manufacture of Portland cement are the Miocene marls and clays of the immediate area.

The Norfolk Portland Cement Corporation's plant[a] located on the southern branch of the Elizabeth River opposite the United States Navy-

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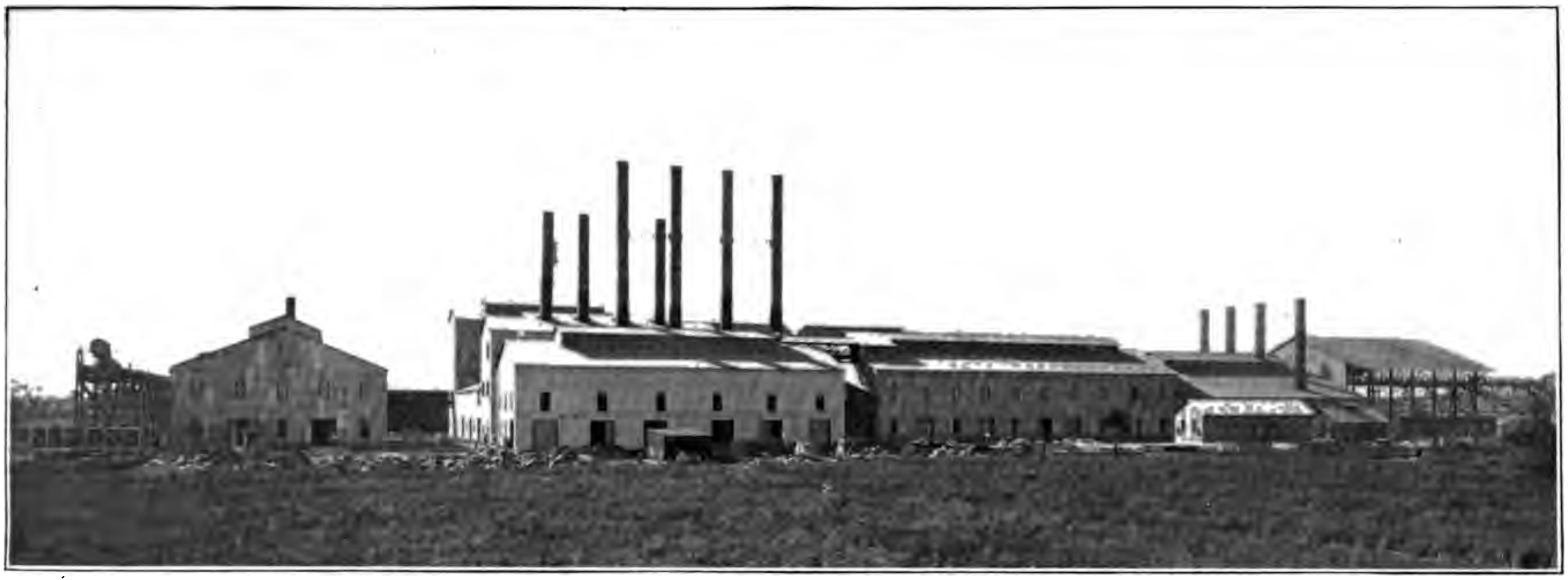
[a] Summarized from an article by Wm. H. Stone in the Manufacturers Record, Oct. 13, 1910, pp. 49-50.

PLATE XVIII.



General view of Norfolk Portland Cement Corporation's plant, opposite U. S. Navy Yard, near Norfolk. Storage bin adjoining wharf shown on left; coal house on right; main portion of plant in center. (Courtesy of Wm. H. Stone, Manufacturers Record.)

NORFOLK PORTLAND CEMENT CORPORATION'S PLANT.

yard at Norfolk, is the first plant built in the South to manufacture Portland cement from shell marl as the principal calcareous material used instead of the hard rock-limestone (Plate XIX, figs. 1 and 2). The marl deposits are located on branches of the James River near Smithfield and Chuckatuck, about 25 miles from the plant. Reported analyses of the marls and clays used as a mix in the making of cement by this plant are as follows:

Analyses of marl and clay from the Norfolk Portland Cement Corporation's property, near Norfolk, Va.

Constituents	Marl	Clay
Silica (SiO_2)	7.24	62.99
Alumina (Al_2O_3) Ferric oxide (Fe_2O_3)	4.92	23.45
Lime (CaO)	47.67	4.82
Magnesia (MgO)	trace	trace

It is reported that previous to building the plant at Norfolk the material from the Virginia marl deposits was shipped during the past 10 years to the American Cement Company at Egypt, Penna., for the manufacture of Portland cement. The cement made at Norfolk is marketed under the American Cement Company's established brand "Giant," a guarantee that the new cement made from the Virginia Coastal Plain marls and clays is in all respects the equal of that upon which the Pennsylvania company has made its reputation.

The company has built a line of railway extending from the large marl and clay deposits which it controls, to a pier constructed for loading the raw materials on barges of 500 tons capacity each, whence they are conveyed to the plant at Norfolk. Upon arrival at the plant the raw materials are delivered from the barges into bins, by buckets having a capacity of 100 tons per hour, operated by two hoisting engines. The bin for marl has a capacity of 500 tons and the one for clay a capacity of 100 tons.

There are four kilns, each of 500 barrels capacity, with provisions for a fifth. After burning to clinker and crushed, the finished product is carried by screw conveyors to the stock houses of which there are two; one used for storing cement shipped by rail and the other on the loading wharf for storing cement to be shipped by water. The plant, covering four and one-half acres, is a large and commodious one, entirely modern and is fully equipped with the necessary machinery, etc. (Plate XVIII).

The Jamestown Portland Cement Corporation's property is located at Yorktown on the south side of York River. The marl beds are exposed in bluffs ranging from a few feet up to 40 and 50 feet along the York River, and in ravines which extend back from the river, the principal one of which is Wormley Creek (Plate XIX, figure 1). The marls are of of Miocene (Yorktown) age. The Yorktown formation in Virginia has a thickness of approximately 125 feet, and is described in detail on pages 158 to 166. A carefully measured section is given on page 161, to which the reader is referred. The maximum working thickness of the formation for cement manufacture at any one place in the vicinity of Yorktown, will probably not exceed 30 feet above stream level. Its general dip varies from 5° to 25° northwest, with an average of about 15°.

Through the courtesy of Mr. H. E. Brown, Chief Engineer of the American Cement Engineering Company, I give below analyses of the marls occurring on the Jamestown Portland Cement Corporation's property. The first four analyses of the marl given below are reported to represent the entire face of the cliff shown in plate XIX, figure 1. Magnesia not exceeding 0.5 per cent is reported as occurring in all of the samples. These different layers are said to be found in practically all of the exposures and in most of the borings which have been made on the property.

Analyses of marls from the Jamestown Portland Cement Corporation's property, Yorktown, Va.

Constituents	I	II	III	IV	V	VI
Silica (SiO_2)	24.06	6.3	12.2	6.2	12.0	9.85
Alumina (Al_2O_3)............	3.29	2.3	1.6	1.3	2.3	2.07
Ferric oxide (Fe_2O_3)	4.47	6.4	4.9	4.9	1.7	2.88
Calcium carbonate ($CaCO_3$) ..	76.71	84.5	80.5	87.1	83.8	78.20
Magnesium carbonate ($MgCO_3$)						0.28
Moisture						1.98

I. A low grade marl ranging from 4 to 6 feet thick at the bottom of the deposit.

II. Average sample of marl taken from a bed 6 to 10 feet thick immediately above I.

III. Average sample of marl taken from a bed 3 to 5 feet thick immediately above II.

IV. Upper bed of marl at top of deposit, overlain by sandy marls 2 to 4 feet thick and too siliceous for use in Portland cement manufacture.

V. Average sample of marl taken from a 10-foot exposure on Wormley Creek.

VI. Average of samples collected from a 15-foot thickness of marl exposed about 500 feet from the bluff shown in plate XIX, figure 1.

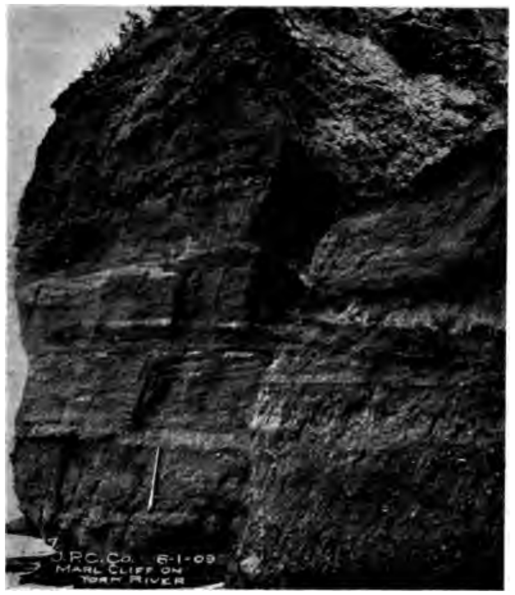


Fig. 1.—View of Miocene (Yorktown) marl beds at Yorktown. (Jamestown Portland Cement Corporation.)

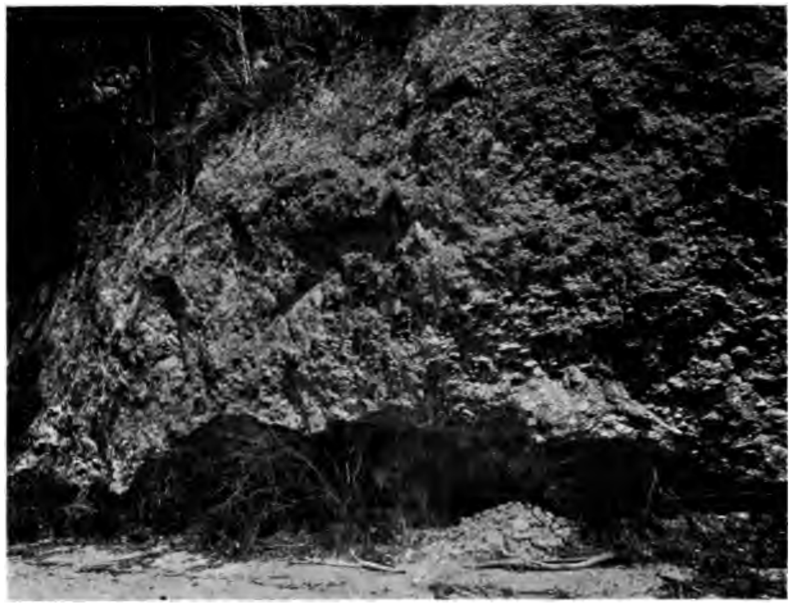


Fig. 2.—View of Miocene (Yorktown) marl beds along north side of James River, south of Grove Station. (Colonial Portland Cement Corporation.)

MIOCENE (YORKTOWN) BEDS.

An analysis of the clays owned by the Jamestown Portland Cement Corporation, and which outcrop on the York River, is reported by Mr. Brown as follows:

Analysis of clay from the Jamestown Portland Cement Corporation's property, Yorktown, Va.

Silica (SiO_2)	65.94
Alumina (Al_2O_3)	22.50
Ferric oxide (Fe_2O_3)	6.60
Lime (CaO)	1.23
Magnesia (MgO)	1.50

A laboratory Portland cement plant owned by the American Cement Engineering Company was erected on the property of the Jamestown Portland Cement Corporation at Yorktown, for demonstrating purposes, in order to manufacture in the ordinary way, and according to mill methods, the marls and clays into standard Portland cement. The raw materials for this plant were secured from many different openings made in the marl deposits, and represent average samples such as will be secured in the operation of steam shovels when the marls are taken from bottom to top of the deposit.

Portland cement was successfully made from the marls occurring at Yorktown, which judging from the results of tests made in a number of the Government and private consulting testing laboratories, is in every respect the equal of many of the standard brands of Portland cement of wide reputation.

The Colonial Portland Cement Corporation's property is located at Grove, Virginia, on the James River and about half a mile from the Chesapeake & Ohio Railway. Two marl beds occur designated as "upper" and "lower," separated by an average thickness of 9 feet of clay, the top of which marks the bottom of the "upper" marl. The beds are exposed in a line of bluffs along the north side of James River, and in ravines which have cut down to a depth of from 20 to 30 feet. Plate XIX, figure 2, is a view of the marl beds exposed in the bluff along the river.

From measurements made in test pits and in natural exposures, the "upper" marl bed shows an average thickness of not less than 12 feet, and in many places it is 30 feet thick. The "lower" marl bed lies immediately below the clay bed and has been exposed to a depth of 10 feet, with the bottom of the bed not reached. The marl and clay beds are of Miocene age and belong to the Yorktown formation.

Numerous samples of the marl have been taken from all points over the property and carefully analyzed with the average results given in columns I and II below.

Analyses of marls from the Colonial Portland Cement Corporation's property, Grove, Va.

Constituents	I	II
Silica (SiO_2)	27.53	26.08
Alumina (Al_2O_3)	2.33	2.15
Ferric oxide (Fe_2O_3)	3.71	3.21
Calcium carbonate ($CaCO_3$)	63.67	65.80
Magnesia (MgO)	0.68	0.68[a]
Water (H_2O)	2.31	1.52[b]

[a] Average of 3 analyses.
[b] Average of 6 analyses.

By a simple process of crushing and screening the high silica in the marl is lowered and the calcium carbonate increased. Two different samples of the marl subjected to the above treatment gave the following results on analysis:

Analyses of marls from the Colonial Portland Cement Corporation's property, Grove, Va.

Constituents	I	II	III	IV
Silica (SiO_2)	5.69	5.81	52.13	53.14
Alumina (Al_2O_3)	1.06	1.18	10.00	8.63
Ferric oxide (Fe_2O_3)	0.86	0.62	6.46	6.16
Calcium carbonate ($CaCO_3$)	89.20	89.48	29.98	35.53
Magnesia (MgO)	.....	0.96	.....	1.14
Water (H_2O)	1.29	1.37	.....	4.55

I and II. Calcareous portion of two samples of marl obtained from crushing and screening.

III and IV. Clayey matter obtained from the two samples of marl as part of the same screening operation.

From a mixture of the two portions separated by screening (calcareous and clayey) a 30-pound sample was mixed and burned in a furnace, cooled, ground and tested by standard methods. The material responded well to all tests, exceeding in each case the standard requirements of Portland cement. It is believed therefore that the extensive marl beds at Grove contain the necessary ingredients for the manufacture of Portland cement, and that by a simple process these ingredients can be combined in a suitable mixture.

The occurrence in the Virginia Coastal Plain of extensive beds of calcareous marls and clays suitable for cement making and which can be readily and cheaply dug, combined with the advantage of location of plants readily accessible to ocean steamers, the cheapness of labor, the mild climate which permits of working in the open air practically the entire year, and the proximity to the coal fields, unite to make this an unusually advantageous area for the manufacture of Portland cement.

MINERAL PAINT.

Brown hematite is frequently present in such large quantities in the Potomac and Lafayette clays as to form an impure ocher. Locally such deposits might be profitably worked, although little attempt has been made to develop them in Virginia. Limonite is present in certain beds in the Miocene in such amounts as to stain them a bright ocher yellow. Frequently it is found in small patches and almost pure but only in few places does it occur in large enough masses and sufficiently pure to be of much value.

Although ocher of more or less purity occurs in a number of places in the Virginia Coastal Plain region, attempts to mine it have been confined to the extreme eastern part of Chesterfield County, 4 miles southwest of Bermuda Hundred, on the Appomattox River. The material is an excellent grade of yellow ocher and was extensively mined for a period of years beginning in 1872, by the American Ocher Company. A high grade ocher was produced, the production amounting to 1,000 tons in 1880. It is said to have been considered by consumers preferable to the Rochelle product and to have materially lowered the market price of all foreign ochers. As a result of the competition, Rochelle ocher fell in price from 3¾ to 1¼ cents per pound. The mine was worked by tunnels extending into the hill from the bluffs of the river. The deposit was reported to have been about 7½ feet thick and is in the upper strata of the Calvert formation.

Three grades were made, all of the same grade but of different degrees of fineness, namely, "single washed," "double washed," and "extra floated." At the shipping point in Virginia, these grades have a value respectively of $18, $21, and $27 per ton.[a] After grinding and washing the product, much of it was sold as yellow ocher, but it is said that greater profits were derived from the sale of red ocher which was obtained by burning the natural product (yellow ocher). Although the deposit does not seem to have been exhausted, the mine has not been in operation since about 1890.

IRON ORE.

Mining of iron ore in Virginia in 1609 by the Jamestown colonists was the first iron ore mined in the United States, of which there is any known record. The successful extraction of the metal from this ore led to the erection of the first iron works in the United States, which were located on Falling Creek in Chesterfield County, about seven miles south of Richmond, between the years 1619 and 1622. The works were destroyed in the Indian massacre of 1622 before they had been operated.

Much iron carbonate ore is present in the Potomac formations of Maryland and many iron furnaces were operated during Colonial days, but the Potomac in Virginia contains much less iron ore, and it is not positively known that any mines were ever worked in these formations in the State. There is a rumor that iron ore was formerly dug near Mt. Vernon.

Although nodules of iron carbonate and iron oxides pure enough to be economically valuable are found, it seems improbable that the Potomac formations of Virginia contain sufficiently large deposits to have much commercial value.

BUILDING STONES.

The building stones of the Coastal Plain are of little importance both on account of their limited occurrence and their inferior quality. In a region in which practically all the rocks are unconsolidated any indurated beds are pretty certain to be utilized locally for the foundations of buildings and for other purposes in which hard compact stones are not demanded. Indurated strata occur in almost every formation in the Coastal Plain of the State, and material from these beds has been employed widely for such local purposes.

The indurated sands (sandstone) of the Patuxent formation furnish the best building stone of the region and quarries have been opened up in these deposits in several places. This sandstone (Map, plate I), occurs in places along the eastern exposure of the crystalline rocks and extends for some distance below the head of tide. The rock is usually variable in texture, light gray or buff in color, and is composed chiefly of quartz and feldspar, the feldspar often decaying rapidly on exposure. The individual grains vary much in size, ranging from bird shot in size up to several inches in diameter.

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[a] Min. Res. of the United States, 1885.

In the early part of the last century much stone was quarried from the Patuxent formation near the mouth of Aquia Creek for use in the construction of public buildings in Washington. The Aquia Creek quarries were purchased by the United States Government in 1791 for the purpose of using the stone in the construction of public buildings in Washington. The stone from these quarries was used chiefly in the construction of many of the older public buildings in the above city, but the quarries were abandoned many years ago largely, it is said, because of the unfitness of the stone for exposed work. The old light house at Cape Henry was also constructed from the same kind of stone. On the Rappahannock River near Fredericksburg, and on the Appomattox River near Bermuda Hundred, similar material has been quarried for local uses. Some of this sandstone is very firmly indurated and forms a fairly good building stone that proves very durable, but in quarrying it much of the rock has to be wasted because of the pockets of loose sand which are frequently encountered.

The indurated marls of Eocene and Miocene age are widely distributed throughout the Coastal Plain and have furnished much material for the construction of foundations. These stones are not especially durable and they cannot be dressed neatly, hence they are used only for economical reasons in the absence of better local materials.

The Lafayette and Columbia formations contain occasional ledges of ferruginous sandstones and conglomerates that have furnished a poor grade of building stone for foundation purposes.

PEAT.

The term peat is applied to a dark-colored nearly black deposit formed by the accumulation and slow decay of vegetable matter under water in bogs and swamps. It is composed chiefly of partly decomposed and disintegrated vegetable matter. When impure and containing too much mineral matter to burn freely the black swamp deposits are more properly called muck. The natural conditions most essential to the formation of peat are restricted access of air, and abundance of water.

When possessing a good degree of purity and properly prepared peat is a good and efficient fuel and may form the basis of a number of manufacturing industries. It has been used but little in America for fuel although repeated attempts have been made to so utilize it in Canada and New England. A large use of peat is in agriculture. Perhaps the largest use now made of peat in the United States is in the manufacture of fertilizer filler, which use seems to be a growing one. When used as a fertilizer, peat may be applied directly to the land or it may be used in composts. It is usually considered preferable, however, to compost the peat before its application to the land. Peat is of value as a fertilizer on account of its absorbent properties and nitrogen content, and because it adds to the humus and hence increases the water-retaining capacity of the soil. A great number of uses of peat other than those mentioned have been proposed, some of which have proved of little or no importance.

The Virginia Coastal Plain contains a very large acreage of swamp lands and some of these swamps contain peat. The most extensive one of these is the Great Dismal Swamp in Virginia and North Carolina, which lies on a fine sandy soil with an approximate slope of about 20 inches to the mile, and is covered by a thick layer of peaty matter. The extent and quality of the peaty matter in the swamps of eastern Virginia are unknown, since these lands have not yet been made the subject of detailed study or investigation.

The Dismal Swamp has been described in considerable detail by Mr. N. H. Darton[a] in the Norfolk folio, and is given on pages 56 to 58 of this volume. The vegetable accumulations of the Dismal Swamp are described by Darton as follows:

"The swamps lie in shallow basins in the surface of the general terrace of the Norfolk region. The basins are now filled to the general level of the surrounding country with vegetable accumulations, which have a maximum thickness of about 20 feet. In recent excavations for a gate on the feeder about half a mile east of Lake Drummond there were exposed 10 feet of peat filled with roots and tree trunks, lying on 8 feet of clear peat which merged with the overlying beds, and this in turn was underlain by fossiliferous sand of late Neocene age. The thickness of the swamp deposits decreases toward the periphery of the present swamp area, but so few excavations have been made along the border zone that the conditions of thinning are not known. The upper beds of peaty materials merge gradually into the sands of the adjoining area, so that no boundary line can be given."

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[a] Norfolk Folio, No. 80, U. S. Geol. Survey, 1902.

Ries[a] quotes the following proximate analysis of peat from the Dismal Swamp in Virginia:

Analysis of peat from the Dismal Swamp, Va.

	Per cent.
Moisture	20.22
Volatile matter	52.31
Fixed carbon	24.52
Fuel ratio	.47

Peat deposits of Pleistocene (Talbot) age are known at numerous points along the Potomac, Rappahannock, and James rivers, in the Virginia Coastal Plain. About 1 mile above Tappahannock, the Rappahannock River has cut into an old Talbot swamp deposit, exposing peat and many upright cypress stumps in an excellent state of preservation. A section is given of this deposit on page —, which shows compact brown to black peat containing numerous cypress stumps and knees in place, etc., of from 1 to 4½ feet in thickness. Buried swamp deposits of Pleistocene age are reported exposed in places by the recent wave-cutting along the western shores of Chesapeake Bay.

Although peat of commercial value may not be found in many of the swamps and bogs of the Coastal Plain, the winning of these lands to the uses of agriculture by dewatering, will afford fertile and productive fields. According to Professor Shaler, the quality of the soil is good and its endurance under cultivation is continuous. The vast acreage of swamp lands in eastern Virginia which at present are practically valueless are so located with reference to the sea that they may be effectively dewatered and won to the uses of agriculture at very considerable profit, in the future.

The proposed drainage of these lands in North Carolina has taken definite shape, and the question is very properly being seriously considered in Virginia, as is indicated by the passage of the Lesner bill by the last General Assembly and by a drainage meeting held at the State Capitol in Richmond on December 15, 1910.

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[a] Ries, H. Economic Geology, 1910, new and revised edition, p. 6.

UNDERGROUND WATERS.

This subject is comprehensively treated in the report on "Underground Waters" of the Virginia Coastal Plain, published as Bulletin V of the Virginia Geological Survey, hence only a brief statement is here made regarding this very important resource.

The water supply of the Virginia Coastal Plain is secured from both shallow and deep wells, and water from both sources is obtainable in almost all parts of the region. The shallow water is found at the base of the Lafayette and Columbia formations at depths ranging from 15 to 60 feet. Most of the region is dependent upon this shallow water, which is generally pure though sometimes contaminated with surface drainage. It rarely contains much mineral matter in solution. The supply of water in these wells is seldom great but is usually sufficient for ordinary domestic purposes except in seasons of excessive drought.

The deep wells of the Coastal Plain furnish uncontaminated water, but much of it is so highly charged with saline materials that it is unserviceable. This is particularly the case in the vicinity of the Bay and Ocean. The deep wells may be divided into two classes, flowing and non-flowing wells. Except in the extreme western portion of the Coastal Plain practically the entire region is underlain by water-bearing strata from which the water will rise from 1 to 20 feet above tide. As a result flowing wells can be usually obtained in the low lands bordering the estuaries. Such wells are very common along the Potomac, Rappahannock, York, and James rivers. The same horizons furnish water for the deep wells over the divides but there the water does not rise to the surface.

The water-bearing horizons of the deep wells are numerous, the lowest of which occurs at the base of the Patuxent formation where it is in contact with the underlying crystalline floor. These basal beds furnish the water supply for many of the wells in Alexandria, but in the central and eastern portions of the region they have seldom been reached. From the western edge of the Coastal Plain this crystalline floor slopes gently to the eastward, and at Fortress Monroe lies 2246 feet beneath the surface. At that point no water was found at the exact contact of the Patuxent deposits with the crystalline rocks, but a supply of salty water was obtained in a coarse sand bed about 15 feet above. In all probability a good supply of water could be obtained almost everywhere at or near the contact in the central and western portions of the region and would not contain enough salt there to render it objectionable.

The Potomac deposits contain many coarse sandy strata above the basal beds and these almost invariably carry water. The variability of the beds, however, does not permit of the correlation of the water-bearing horizons except in very closely contiguous regions.

The Eocene beds of Virginia contain some coarse sand strata, which usually carry considerable water in the central part of the Coastal Plain. The flowing wells at Colonial Beach obtain a large supply of fine water from these strata at a depth of 250 feet, while the Eocene beds at Naylor's Wharf furnish an ample supply at depths ranging from 275 to 325 feet.

The Miocene formations contain many artesian water horizons which produce flowing wells along the larger streams. According to Darton these waters underlie a belt of country about 20 miles in width lying to the east of a line extending from Mathias Point on the Potomac River to Emporia. Miocene waters can also be obtained to the east of this belt, but they are so apt to be heavily charged with salt that it is usually advisable to seek water in deeper strata.

SOILS.

In the Coastal Plain of Virginia there is a great variety of soil types, each possessing special adaptability to certain crops. The region is strictly an agricultural one, consequently great interest is attached to the character of the soils. The soils of a region are formed from the surface portions of the underlying geological formations with which is mixed more or less humus from decaying vegetation. For example, the soils formed from the greensands of the Eocene are distinctive and very unlike those formed from the diatomaceous earth beds of the Miocene. On account of the greater or less diversity in the deposits of a single formation it will not everywhere, however, give rise to the same kind of soil. The Calvert formation, for example, embraces all the deposits formed during a certain period of submergence including clays, sands, diatomaceous earth, and shell beds. The soils formed from the deposits of this formation will therefore vary as much as the strata from which they are derived. Furthermore, the same soil types may be produced from geological formations of different age. It is important then to study in great detail the stratigraphy of the various formations, in order fully to interpret the soils.

The soils of the Coastal Plain are, for the most part, derived from the Lafayette and Columbia formations which appear at the surface over much the larger portion of Tidewater Virginia. The character of these beds, however, is so largely dependent upon the underlying strata that indirectly the older formations affect the character of the soils even where they do not appear at the surface.

Sands, clays, loams, and gravels constitute largely the surface materials and from these most of the soils have been derived. The United States Bureau of Soils has differentiated a great many soil types in the Coastal Plain but these may be classed under four heads—clay soils, loam soils, sand and gravel soils, and swamp and flood-plain soils.

The heavy clay soils form a narrow belt in the northwestern part of the Coastal Plain, being well developed trom Fredericksburg to Washington. The soils which are plastic and usually red in color are formed from the Potomac deposits and are of little value for agricultural purposes. Most of the region is covered with scrub pine though some areas are under cultivation. Cucumbers can be raised more profitably on this type of soil than almost any other crop and to the north of Fredericksburg they are extensively grown.

The loam soils include those soil types which are more specifically referred to as the clay loams and sandy loams. The former are very extensively developed over the divides in the central and western portions of the Coastal Plain and occur in smaller areas in the eastern parts of the region. These soils are formed from the clay loam facies of the Lafayette and Columbia deposits and are among the most productive soils of the region. They are well adapted to the cultivation of grass, hay, small grain and corn. They are less productive in regions where the sand constitutes a large part of the soils producing a sandy loam and such areas are usually covered with pine forests.

The soils largely composed of sand have their greatest development in the extreme eastern part of the State and although naturally less productive than the loam soils are yet far more important because of the early maturity of the crops. The great trucking regions of the State occupy the eastern portion of the Coastal Plain and here are grown enormous quantities of early vegetables and potatoes for the Washington, Baltimore, Philadelphia, New York, and Boston markets. In some places the soil itself is considered as little more than a medium in which the artificial fertilizers can be held, as the nourishment for the plants consists almost entirely of these added products. The loose open textures of the soils permit easy underground drainage which tends to hasten the maturity of the crops.

The swamp and flood-plain soils constitute several distinct soil types in which there is a large admixture of vegetable humus. These are the richest soils of the Coastal Plain and are developed on the low lands bordering the streams and Chesapeake Bay. Large crops are grown on these soils which are especially adapted to corn and hay. Vegetables of all kinds thrive and attain a greater size than those grown in the sandy soils but as late truck does not command good market prices few vegetables are raised on these soils.

The United States Bureau of Soils has mapped and described the soils of four areas within the Coastal Plain of Virginia that are widely separated, namely, Norfolk,[a] Hanover County,[b] Yorktown,[c] and Chesterfield County.[d] The numerous soil types represented in the four areas may be considered as typical of the soils in general of the Coastal Plain. The texture of typical samples of the soils and subsoils mapped and described by the Bureau of Soils is shown in the tables of mechanical analyses below.

Twelve types of soils are differentiated in the Hanover County Survey. Of these, four (Cecil sandy loam, Cecil clay, Cecil sand, and Meadow) belong to the Piedmont portion of the area surveyed, and the remaining eight to the Coastal Plain.

Areas of different soils.

Soil	Acres	Per cent.
Cecil sandy loam	97,856	32.2
Norfolk sandy loam	88,256	29.0
Norfolk fine sandy loam	39,232	12.9
Cecil sand	29,696	9.8
Meadow	15,552	5.1
Cecil clay	7,360	2.4
Leonardtown loam	6,784	2.2
Swamp	6,208	2.1
Wickham sandy loam	5,120	1.7
Wickham sand	4,416	1.4
Wickham clay loam	2,176	.7
Norfolk gravelly loam	1,344	.5
Total	304,000	....

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[a] Lapham, J. E. Soil Survey of the Norfolk Area, Virginia. U. S. Dept. of Agl., Bureau of Soils, 1903 (1904), Fifth Report, pp. 233-252.

[b] Bennett, H. H. and McLendon, W. E. Soil Survey of Hanover County, Virginia. Idem. 1905 (1907), Seventh Report, pp. 213-245.

[c] Burke, R. T. Avon and Root, A. S. Soil Survey of the Yorktown Area, Virginia. Idem. 1905 (1907), Seventh Report, pp. 247-270.

[d] Bennett, F., Winston, R. A., Geib, W. J., and Mann, C. W. Soil Survey of Chesterfield County, Virginia. Idem. 1906 (1908), Eighth Report, pp. 195-222.

The following tables give the average results of mechanical analyses of the seven types of soil differentiated by the Bureau of Soils in Hanover County:

Mechanical analyses of Norfolk sandy loam.

Description	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Soil	1.0	14.7	14.1	35.5	13.0	14.1	6.6
Subsoil	.7	8.3	10.9	34.0	12.7	14.7	18.5

Mechanical analyses of Norfolk fine sandy loam.

Soil	0.4	3.6	5.5	28.4	26.2	27.9	7.8
Subsoil	.4	3.0	4.5	24.0	20.2	24.8	23.0

Mechanical analyses of Wickham clay loam.

Soil	0.8	3.4	4.5	27.3	24.7	22.2	16.4
Subsoil	.3	1.4	2.6	15.9	21.8	24.3	33.7

Mechanical analyses of Wickham sandy loam.

Soil	2.2	16.1	15.5	23.5	13.6	16.8	12.0
Subsoil	1.5	13.0	14.3	21.2	10.9	15.7	23.2

Mechanical analyses of Wickham sand.

Soil	7.1	30.8	12.4	16.7	13.0	10.6	9.2
Subsoil	6.3	27.8	13.4	18.9	13.0	10.2	10.2

Mechanical analyses of Norfolk gravelly loam.

Soil	6.9	19.4	18.8	21.1	6.8	19.0	7.7
Subsoil	8.7	27.5	13.4	17.4	4.6	8.0	20.2

Mechanical analyses of Leonardtown loam.

Soil	1.4	6.8	5.2	21.3	19.4	27.2	18.6
Subsoil	.9	6.2	4.9	17.9	17.9	22.7	28.9

Eleven types of soils are differentiated by the Bureau of Soils in the Yorktown area, which range in texture from clay and silt to fine gravel, with the predominating types consisting of fine to medium sandy loams. The following table gives the names and extent of the several soils in the area surveyed.

Areas of different soils.

Soil	Acres	Per cent.
Norfolk fine sandy loam	144,064	37.6
Norfolk sandy loam	94,016	24.5
Leonardtown loam	36,800	9.6
Portsmouth fine sandy loam	29,760	7.8
Swamp	26,368	6.9
Galveston clay	21,568	5.7
Portsmouth sandy loam	20,032	5.2
Norfolk coarse sandy loam	4,288	1.1
Portsmouth clay loam	2,176	.6
Galveston sand	1,984	.5
Norfolk clay loam	1,856	.5
Total	382,912	....

The following tables give the average results of mechanical analyses of the eleven types of soils mapped and described by the Bureau of Soils.

Mechanical analyses of Portsmouth fine sandy loam.

Description	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Soil	0.4	3.1	6.5	47.9	7.3	21.1	13.5
Subsoil	.2	2.2	4.2	32.8	9.2	27.4	21.5

Mechanical analyses of Norfolk clay loam.

Soil	1.0	3.2	7.6	22.6	7.1	34.8	23.9
Subsoil	.5	3.6	6.1	17.8	6.9	32.2	32.9

Mechanical analyses of Portsmouth clay loam.

Soil	0.1	1.3	4.5	26.5	7.7	38.4	21.3
Subsoil	.2	1.9	4.9	28.7	4.8	38.2	21.0

Mechanical analyses of Portsmouth sandy loam.

Soil	0.9	5.9	14.4	39.2	16.8	14.6	7.9
Subsoil	.5	5.1	12.0	38.4	4.7	16.9	22.1

Mechanical analyses of Leonardtown loam.

Soil	0.7	3.9	4.5	21.9	14.7	42.2	13.7
Subsoil	.9	2.2	3.2	17.3	9.4	36.3	29.1

Mechanical analyses of Norfolk coarse sandy loam.

Soil	16.4	27.9	8.9	12.2	2.5	18.7	13.0
Subsoil	16.3	30.0	8.2	7.9	1.9	19.8	15.1

Mechanical analyses of Norfolk sandy loam.

Soil	0.4	9.4	13.8	46.3	10.3	11.3	7.6
Subsoil	.9	10.0	13.1	38.6	11.1	12.6	13.6

Mechanical analyses of Norfolk fine sandy loam.

Soil	2.2	4.8	9.9	39.6	10.2	25.5	9.3
Subsoil	3.2	4.3	8.6	33.9	8.0	24.0	20.5

Mechanical analyses of Galveston sand.

Soil	0.8	19.8	21.8	49.9	1.7	3.4	2.5
Subsoil	1.6	22.8	26.7	36.0	2.4	6.6	3.7

The Bureau of Soils has recognized and mapped in the Norfolk area seven distinct types of arable soils, and two nonarable types (Galveston sand and Swamp). The table below gives the area and extent of each of these types.

Areas of different soils.

Soil	Acres	Per cent.
Leonardtown loam	53,952	27.8
Norfolk fine sandy loam	38,144	19.7
Portsmouth sandy loam	30,016	15.4
Norfolk loam	23,872	12.3
Norfolk sand	20,864	10.7
Swamp	12,928	6.7
Galveston sand	10,752	5.5
Portsmouth sand	2,048	1.1
Leonardtown gravelly loam	1,536	.8
Total	194,112	....

Of the seven arable types of soils in the Norfolk area, six (Leonardtown loam, Norfolk fine sandy loam, Portsmouth sandy loam, Norfolk loam, Norfolk sand, and Portsmouth sand) are good trucking soils, while the remaining one (Leonardtown gravelly loam) is best adapted to the growth of ordinary farm crops.

The tables below show the texture of typical samples of the soil and subsoil of the seven arable types mapped and described by the Bureau of Soils in the Norfolk area.

Mechanical analyses of Norfolk sand.

Locality	Description	Organic Matter.	Gravel, 2 to 1 mm.	Coarse Sand, 1 to 0.5 mm.	Medium Sand, 0.5 to 0.25 mm.	Fine Sand, 0.25 to 0.1 mm.	Very Fine Sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
¼ mile W. of West Norfolk	Brown medium sand, 0 to 12 inches	1.60	0.20	4.64	17.86	46.96	4.32	18.92	6.88
1½ miles N. of Belleville	Brown medium sand, 0 to 12 inches	.36	.04	1.22	7.52	55.90	13.96	14.18	7.16
1 mile SW. of Niles	Brown sand, 0 to 12 inches	.92	.02	1.16	4.30	55.22	12.70	18.14	8.24
Subsoil of 8702	Loose yellow sand, 12 to 36 inches	.50	.04	.46	4.12	56.80	15.50	15.52	7.46
Subsoil of 8704	Yellow medium sand, 12 to 30 inches	.83	.10	4.42	17.10	44.70	3.92	20.24	9.52
Subsoil of 8700	Loose to plastic sand, 12 to 36 inches.	.31	.04	.50	7.28	47.42	13.28	19.20	12.22

Mechanical analyses of Norfolk fine sandy loam.

Locality	Description	Organic Matter.	Gravel, 2 to 1 mm.	Coarse Sand, 1 to 0.5 mm.	Medium Sand, 0.5 to 0.25 mm.	Fine Sand, 0.25 to 0.1 mm.	Very Fine Sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
½ mile NE. of Oceana	Medium sandy loam, 0 to 11 inches	0.87	1.34	21.14	21.90	15.84	5.66	26.64	7.46
2 miles SW. of Churchland	Medium sandy loam, 0 to 11 inches	1.33	.00	.54	4.76	54.62	13.42	18.14	8.52
2 miles W. of West Norfolk	Medium sandy loam, 0 to 12 inches	1.63	.28	2.34	11.70	52.74	7.60	16.46	8.62
Subsoil of 8708	Sand to sandy loam, 12 to 36 inches	.21	.22	2.06	11.32	46.62	5.50	23.42	10.78
Subsoil of 8706	Fine sandy loam, 11 to 36 inches	.29	.10	.26	4.30	53.64	12.40	17.32	11.74
Subsoil of 8710	Fine sandy loam, 11 to 36 inches	.40	.96	16.74	21.90	14.72	3.00	27.88	14.70

Mechanical analyses of Portsmouth sandy loam.

Locality	Description	Organic Matter.	Gravel, 2 to 1 mm.	Coarse Sand, 1 to 0.5 mm.	Medium Sand, 0.5 to 0.25 mm.	Fine Sand, 0.25 to 0.1 mm.	Very Fine Sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
5 miles SW. of Portsmouth	Fine black loam, 0 to 12 inches	7.01	0.16	1.50	21.68	32.04	3.20	28.10	12.04
½ mile E. of Churchland	Sandy loam, 0 to 8 inches	2.84	.06	1.46	5.80	55.40	6.50	18.42	12.36
Subsoil of 8716	Silty fine sand, 12 to 36 inches	.58	.00	.70	24.22	36.74	2.10	21.38	14.86
Subsoil of 8714	Sticky sandy loam, 8 to 36 inches	1.04	.12	.68	3.30	53.06	6.94	18.74	17.14

Mechanical analyses of Norfolk loam.

Locality	Description	Organic Matter.	Gravel, 2 to 1 mm.	Coarse Sand, 1 to 0.5 mm.	Medium Sand, 0.5 to 0.25 mm.	Fine Sand, 0.25 to 0.1 mm.	Very Fine Sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
1 mile NW. of Herbert	Fine sandy loam, 0 to 9 inches	0.89	0.60	3.24	12.82	37.94	11.14	27.68	6.58
2 miles NW. of Jacksondale	Fine sandy loam, 0 to 12 inches	1.79	.50	5.70	18.12	27.16	3.56	35.02	9.62
1 mile SW. of Virginia Beach	Brown sandy loam, 0 to 12 inches	1.94	.28	8.90	16.14	16.58	5.44	42.20	9.66
Subsoil of 8684	Fine sandy loam, 12 to 36 inches	.48	.50	4.46	17.20	26.04	3.08	36.14	12.18
Subsoil of 8686	Yellow sandy loam, 9 to 36 inches	.38	.28	1.54	9.06	27.84	8.70	35.32	16.98
Subsoil of 8682	Fine sandy loam, 12 to 36 inches	.56	.52	6.80	14.34	13.96	3.70	40.28	20.38

Mechanical analyses of Leonardtown loam.

Locality	Description	Organic Matter	Gravel, 2 to 1 mm.	Coarse Sand, 1 to 0.5 mm.	Medium Sand 0.5 to 0.25 mm.	Fine Sand, 0.25 to 0.1 mm.	Very Fine Sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1 mile SE. of Kempsville	Gray silty loam, 0 to 9 inches	1.84	0.58	1.34	2.48	12.76	5.10	66.86	10.82
1 mile N. of Princess Anne C. H.	Fine silty loam, 0 to 9 inches	2.17	.10	1.14	2.44	4.28	6.22	69.66	16.16
1½ miles NW. of Sigma	Fine gray silt, 0 to 9 inches	2.76	.06	.42	.46	1.82	8.94	68.60	19.70
Subsoil of 8696	Fine gray silt, 9 to 36 inches	.35	.00	.10	.20	1.30	7.66	70.98	19.76
Subsoil of 8694	Silt, 9 to 36 inches	.81	.16	.80	1.56	7.48	3.44	57.00	29.56
Subsoil of 8692	Gray silty loam, 9 to 36 inches	.47	.04	.46	.90	1.32	5.80	58.70	32.56

Mechanical analyses of Loanardtown gravelly loam.

3½ miles NE. of Waterworks	Gray silty loam, 0 to 9 inches	2.54	12.02	9.94	3.68	4.76	4.84	48.24	16.46
Subsoil of 8698	Gray silty loam, 9 to 36 inches	.45	18.54	19.38	3.62	5.00	6.88	28.74	17.72

Mechanical analyses of Portsmouth sand.

1¾ miles SW. of Portsmouth	Coarse gray sand, 0 to 12 inches	1.55	0.18	4.66	57.46	31.40	1.20	3.30	1.38
3½ miles SW. of Portsmouth	Coarse gray sand, 0 to 10 inches	2.71	.06	3.62	50.50	31.72	1.34	6.26	6.50
Subsoil of 8688	Coarse sand, 12 to 36 inches	.42	.16	5.80	50.38	37.14	1.80	2.90	1.82
Subsoil of 8690	Brown medium sand, 10 to 36 inches	1.77	.10	2.52	49.98	31.00	1.36	7.06	7.98

Twelve soil types are differentiated by the Bureau of Soils in the Chesterfield County Survey. The soils are described as being light-textured sands, sandy loams, and loams. About four-fifths of the mapped area lies within the Piedmont region and the principal soils are Chesterfield gravelly sandy loam, Chesterfield sandy loam, and Bradley sandy loam. The principal Coastal Plain soil types represented include the Norfolk sand, the Norfolk sandy loam, and the Norfolk fine sandy loam.

There is given in the table below the name and extent of the twelve soil types mapped in the Chesterfield County area.

Areas of different soils.

Soil	Acres	Per cent.
Chesterfield sandy loam	95,680	31.1
Bradley sandy loam	59,072	19.3
Chesterfield gravelly sandy loam	34,304	11.2
Norfolk sandy loam	32,704	10.7
Meadow	25,088	8.2
Elkton fine sandy loam	14,656	4.8
Norfolk sand	11,200	3.7
Congaree loam	9,984	3.3
Norfolk fine sandy loam	8,832	2.9
Norfolk silt loam	5,952	2.0
Wickham loam	5,952	2.0
Swamp	2,432	0.8
Total	305,856	....

The tables below give the average results of mechanical analyses of the principal Coastal Plain soil types in the area mapped, which are the Norfolk sand, the Norfolk sandy loam, and the Norfolk fine sandy loam.

Mechanical analyses of the Norfolk fine sandy loam.

Description	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Soil	0.6	3.6	4.7	23.1	20.3	40.1	7.5
Subsoil	.1	2.1	2.7	16.0	12.2	35.9	30.7

Mechanical analyses of Norfolk sandy loam.

Soil	2.5	21.9	16.9	24.7	6.9	20.9	6.1
Subsoil	1.7	17.0	9.4	19.7	7.7	20.1	24.1

Mechanical analyses of Norfolk sand.

Soil	2.6	18.3	12.1	31.5	10.8	18.8	5.2
Subsoil	4.2	23.0	11.5	29.9	9.5	15.6	6.4

Darton[a] gives the following description of the swamp soils in the Norfolk quadrangle.

"The soils of the swamps vary from pure peat to clayey loam. Two leading varieties are recognized, the 'Juniper' or 'light' swamp, and the 'black gum' or 'dark' swamp. The first is nearly pure peat, consisting of a brown mass of vegetal fragments derived from the juniper or white cedar, which is the characteristic tree of 'light' swampy areas. The thickness of the deposit is often 8 to 10 feet. From 75 to 95 per cent of the material is organic. When such land is cleared and drained the peat cakes and hardens so that it resembles charred wood. Land of this sort is practically worthless. The black gum swamp deposits which have been laid down in various portions of the Dismal and other swamps and which bear a forest of cypress, black gum, and red maple, are well adapted to agriculture in most cases. This soil contains a large amount of organic matter which is mainly in its upper portion. When it is properly drained and cultivated the amount of organic matter gradually diminishes, but it has been found in the drained areas that after being under cultivation for fifty years the soil still retains enough organic matter to remain black in color. The organic matter furnishes nitrogenous materials to plants, so that the soil is a rich one, but its disposition to retain moisture renders it rather slow for the raising of early vegetables. The soils are also notably acid, which has to be neutralized by repeated applications of lime. The percentage of clay in the swamp soils is large, for the sluggish drainage in the swampy areas does not bring much sand, and the principal inorganic sediments are very fine flocculent clayey materials. This character greatly retards artificial drainage of the region, so that in reclaiming swamp lands numerous ditches and extensive tiling are necessary * * * *. There are extensive areas of the swamp which can be economically drained and which have rich and lasting soils, and the region has good prospects of being valuable agriculturally in the future. It is not expected that the soils will be available for truck farming to the same extent as the dry plains of the surrounding region, but they will yield crops of many important staples."

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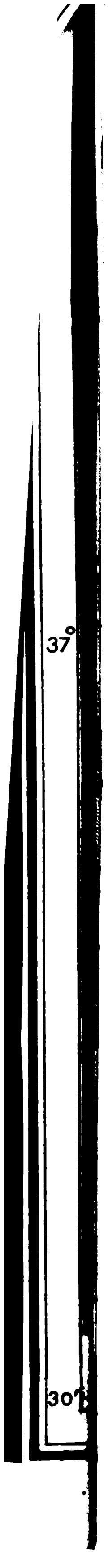
[a] Norfolk Folio, No. 80, U. S. Geol. Survey, 1902, p. 4.

INDEX

Accotink sections, 80.
Alderman, E. A., 3.
Analyses, clays, 224.
  diatomaceous earth, 243.
  greensand marl, 249.
  marl, 253, 254.
  molding sands, 240.
  soils, 266, 267, 268, 269, 270, 271.
Analysis of peat, 261.
Appomattox River sections, 79, 139.
Aquia Creek sections, 82, 94.
Aquia formation, 90, 200.
Arundel formation, 66.
Ashland section, 137.
Barringer, P. B., 3.
Bayport section, 144.
Beacon's Quarter Branch, 177.
Benn's Church section, 164.
Berry, E. W., 61.
Bibliography, 19.
Blackwater River sections, 149.
Blairs Wharf section, 139.
Bowling Green section, 136.
Bowman, A. M., 3.
Branch's Bridge section, 156.
Brigg's Creek section, 166.
Brooke section, 83.
Building stone, 258.
Burdette section, 151.
Burham's Wharf section, 145.
Burke's Bridge section, 111
Calcareous marl, 249.
Calhoun Creek section, 166.
Calvert Formation, 126, 203.
Carter's Wharf section, 134.
Cenozoic, 88.
Chaffin bluff section, 75.
Chesapeake Group, 125.
Chickahominy River sections, 101, 145, 182.
Choptank formation, 140.
Chuckatuck section, 164.
City Point sections, 115, 116.
Claremont Wharf section, 146.
Clark, Wm. Bullock, 13.
Clays, 223.
Coastal lagoons, 47.
Coastal Plain, geology of, 59.
  subaerial division, 48.
  submarine division, 46.
Cobbs Wharf section, 153.
Cockpit Point section, 71.
Columbia Group, 179.
Commission, Geological, 3.
Contents, 4.
Correlation of Coastal Plain formations, 191.
Cretaceous, 61, 191.
Cypress Bridge section, 154.
Deep Bottom section, 78.
Diatomaceous earth, 243.
Dillard's Wharf section, 147.
Dismal Swamp, 56.
Drainage of the Coastal Plain, 52.
Drewry's Bluff section, 75.
Dumfries Wharf section, 72.
Dutch Gap canal, 77.
Economic products, 223.
Elmwood Creek section, 133.
Eocene, 88, 200.
Eocene fauna, distribution of, 117.
Everett's Creek section, 165.
Exit Post-office section, 165.
Ferguson's Wharf section, 163.
Franklin section, 152.
Geological history of the Coastal Plain, 210.
Geology of the Coastal Plain, 59.
Glymont section, 93.
Gravel, 241.
Greensand marl, 247.
Gunston Cove bluff section, 70.
Hanover Courthouse section, 100.
Hopyard section, 108.
Howlett House bluff, sections, 78, 102.
Illustrations, 8.
Infusorial earth, 243.
Iron ore, 258.
James River sections, 74, 101, 102, 115, 129, 138, 146, 162.
Jetts Creek section, 110.
Jones Point section, 143.
King's Creek section, 161.
King's Mill section, 163.
Lafayette formation, 176, 205.
Lafayette stage, 219.
Lafayette terrace, 49.
Lagoons, coastal, 47.
Lanexa section, 145.
Letter of transmittal, 10.
Lieutenant Run section, 139.
Literature referring to the Virginia Coastal Plain, 19.
Lorton section, 81.

Lower Cretaceous, 61, 191.
Mann, Wm. Hodges, 3.
Marl, 247.
Marricossick Creek sections, 113, 136.
Massaponax Creek section, 74.
Matadequin Creek section, 115.
Mattaponi River sections, 99, 110, 135, 137.
Meherrin River section, 155.
Mesozoic, 61.
Miller, B. L., 13.
Mineral paint, 257.
Miocene, 125, 202.
Miocene fauna, distribution of, 167.
Morgart's section, 163.
Mount Creek section, 108.
Mount Folly section, 146.
Nanjemoy formation, 103, 201.
Nańsemond River section, 166.
Newcastle section, 114.
Nichols, E. W., 3.
Nomini Cliffs sections, 129, 130.
Norfolk section, 187.
Northern Neck sections, 142.
Nottoway River sections, 153.
Off-shore beaches and bars, 47.
Old Seine Hole Landing section, 149.
Pamunkey Group, 88.
Pamunkey River sections, 100, 114.
Passapatanzy section, 106.
Patapsco formation, 67, 194.
Patuxent formation, 63, 192.
Peat, 259.
Physiographic record, 219.
Physiography, 46.
Physiography and geology, 13.
Pleistocene, 179, 206.
Pliocene (?), 175, 205.
Pohick sections, 81.
Point of Rocks sections, 79, 80.
Popes Creek sections, 129, 131.
Port Conway section, 109.
Potomac Creek section, 95, 106, 107.
Potomac flora, distribution of, 84.
Potomac Group, 61.
Potomac River sections, 69.
Potomac Run section, 95, 105.
Powells Creek section, 81.
Preface, 11.
Proctor Creek section, 75.
Punch Bowl Point section, 144.
Quaternary, 179, 205.
Ramancoke section, 138.
Rappahannock River sections, 73, 96, 97, 98, 99, 107, 132, 143, 186.
Recent formations, 189, 209.
Recent stage, 222.
Recent terrace, 51.
Reedy's Mill bridge section, 112.
St. Mary's formation, 141, 203.
Sand and gravel, 239.
Schmidt's Bluff section, 147.
Scotland Wharf section, 148.
Sections, detailed, 69, 93, 105, 128, 160.
Seventy-two Mile Post section, 82.
Shell marl, 249.
Silica, 243.
Smith Creek section, 175.
Soils, 263.
South Quay section, 152.
Stafford section, 96.
Stream courses, 53.
Subaerial division of the Coastal Plain, 48.
Submarine division of the Coastal Plain, 46.
Suffolk section, 184.
Sunderland formation, 181, 207.
Sunderland stage, 220.
Sunderland terrace, 49.
Sycamore section, 154.
Talbot formation, 185, 208.
Talbot stage, 221.
Talbot terrace, 50.
Tappahannock sections, 134, 135, 186.
Terraces, 48.
Tertiary, 88, 199.
Tide-water estuaries, 54.
Tripoli, 243.
Underground waters, 262.
Union Mills section, 143.
Upper Cretaceous, 87, 195.
Walkerton section, 137.
Waterview Wharf section, 144.
Watson, Thomas L., 3, 223.
White House bluff section, 70.
Wickham section, 100.
Wicomico formation, 183, 207.
Wicomico stage, 220.
Wicomico terrace, 50.
Widewater section, 72.
Wilmont Wharf section, 133.
Woodstock section, 106.
York River sections, 146, 160.
Yorktown formation, 158, 204.
Zuni sections, 149, 150.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VIRGINIA GEOLOGICAL SURVEY
UNIVERSITY OF VIRGINIA
THOMAS LEONARD WATSON, PH. D.
DIRECTOR

Bulletin No. V

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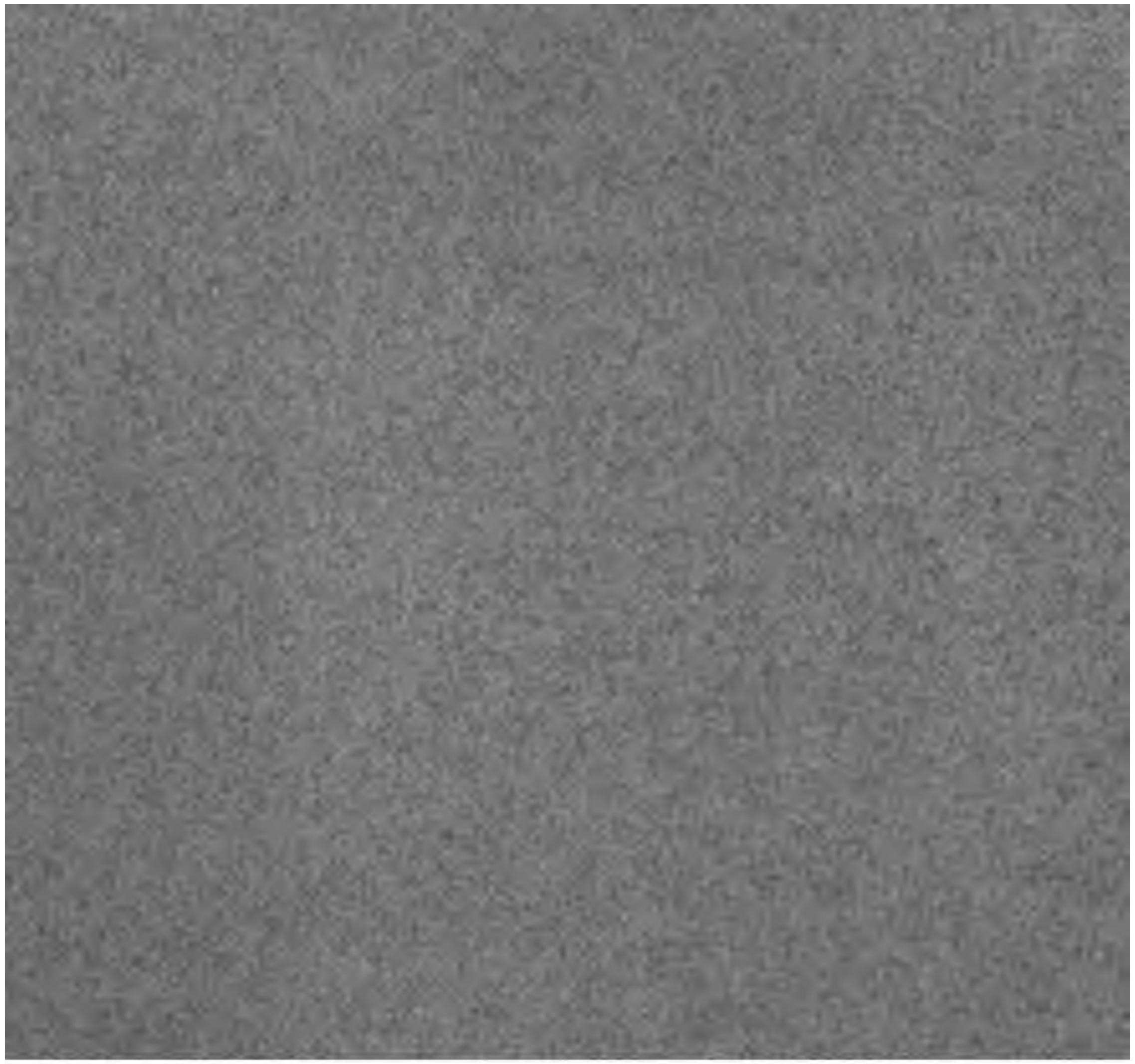

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CHARLOTTESVILLE
UNIVERSITY OF VIRGINIA
1913

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CONTENTS

PAGE

INTRODUCTION 1
  Scope of report 1
  Acknowledgments 1
  Literature 2
  Results of investigation 3

TOPOGRAPHIC AND GEOLOGIC PROVINCES OF VIRGINIA 5
      General statement 5
    Piedmont Plateau 5
      General description 5
    Coastal Plain 7
        General description 7
      Geographic position 7
      Climate 7
      Topography 10
          General description 10
          Terraces or terrace plains 10
          Topographic types 10
      Geologic relations of Coastal Plain deposits 11
          General description 11
          Thickness of deposits 11
      Crystalline rocks 12
          Character and extent 12
          Bed-rock topography 12
      Water supplies 13

SEDIMENTARY DEPOSITS 14
  Cretaceous 14
    Lower Cretaceous 14
      Potomac group 14
        Extent and character 14
        Origin 15
      Divisions 15
            Patuxent formation 15
            Patapsco formation 15
      Water supplies 16
    Upper Cretaceous 16
  Tertiary 17
    Eocene 17
      Pamunkey group 17
        Extent and character 17
      Divisions 18
            Aquia formation 18
            Nanjemoy formation 18
      Water supplies 19
    Miocene 19
      Chesapeake group 19
        Extent and character 19
      Divisions 20
            Calvert formation 20
            Choptank formation 20
            St. Mary's formation 20
            Yorktown formation 20
      Water supplies 21
    Pliocene (?) 21
      Lafayette formation 21
        Extent and character 21

PAGE
Origin 22
Water supplies 22
Pleistocene 23
Columbia group 23
Character and extent 23
Divisions 23
Sunderland formation 25
Wicomico formation 25
Talbot formation 25
Origin 25
Water supplies 26
Undifferentiated Columbia beds 26
Extent and character 26
Water supplies 27
Summary of geologic formations and their water supplies 28

UNDERGROUND WATERS 31
Origin, occurrence, and distribution 31
General statement 31
Evaporation 31
Run-off 31
Controlling factors in soil absorption 31
Storage capacity of soils 32
Soils and soil solutions 32
Soils 32
Soil solutions 36

GROUND WATER 37
Definition of ground water 37
Water table 37
Fluctuations of water table 37
Perched ground water 38
Circulation of ground water 39
Rate of movement of underground water 40
Underground lakes and rivers 41
Ground water temperature 41
Chemical composition of ground water 41
Normal chlorine 42
Pollution of ground water 43
Areal extent of pollution 43
Emergence of ground water 44
Seeps 44
Springs 44
Types of Coastal Plain springs 45
Normal springs 46
Perched springs 46
Artesian springs 46
Sources of spring waters 46
Permanence of flow 47
Purity of supply 47
Pollution of spring sources 47
Quality of spring waters 48
Deep and artesian waters 48
Function of ground water 48
Deep circulation 48
Temperatures of deep water 49
Composition of deep water 51
Artesian waters 51

PAGE
Definition of artesian........ 51
Artesian conditions........ 51
Coastal Plain an artesian slope........ 52
Source of artesian water........ 52
Initial head........ 53
Loss of head........ 53
Ponded water........ 53
Fluctuations of level in artesian wells........ 54
Quality of artesian waters........ 54
Artesian sands........ 55
Number........ 55
Potomac sands........ 56
Pamunkey sands........ 56
Chesapeake sands........ 57
Columbia sands........ 58
Flowing well areas........ 58
Conservation of artesian supplies........ 59

RECOVERY OF WATER........ 60
Cisterns........ 60
Springs and seeps........ 60
Improvement of springs........ 61
Use of rams........ 61
Collecting tunnels and drains........ 61
General statement........ 61
Mount Vernon collecting tunnels........ 62
Wells........ 63
Dug wells........ 63
Bored wells........ 64
Driven wells........ 64
Drilled wells........ 65
Magnetic wells........ 68
Yield of wells........ 68
Losses of head or yield in flowing wells........ 69
Causes........ 69
Faults in sinking........ 70
Faults in maintenance........ 70
Neglect........ 70
Abuse........ 70
Interference........ 71
Utilization of supply........ 72
Rams at flowing wells........ 73
Sanitary protection of wells........ 73
Public health as related to underground water supply........ 75
Municipal water supplies........ 75
Source of supply........ 75
Surface water........ 75
Underground water........ 76
Suitability of surface and underground waters for municipal needs........ 76
Notes on city and town supplies........ 76
Mineral waters........ 82
Value of mineral waters........ 83
Deep wells in crystalline rocks........ 83
General statement........ 83
Wells near Richmond........ 85
General conditions........ 85
Wells near river front........ 85
Richmond Paper Co........ 85

PAGE
- Albemarle Paper Co. 85
- Other wells 86
- Wells near the center of the city 86
  - Hotel Jefferson 86
  - Chesterfield apartments 87
  - Murphy's hotel 88
  - Richmond hotel 89
- Wells in the northwestern part of Richmond, etc 90
- Wells south of Richmond 92
- Emporia 93
- Probability of finding water by deep wells 94
- Analyses of waters from wells in crystalline rocks near Richmond 94
  - Changes in quality of the water 97
- Deep waters of the Norfolk-Newport News area 97
  - General statement 97
  - Limits of area 98
  - Deep wells north of James River 99
    - Fort Monroe 99
    - Newport News 101
    - Back River 102
    - Hotel Chamberlain 104
  - Deep wells south of James River 106
    - General statement 106
    - Virginia Beach 107
    - Masons Creek 107
    - Money Point 107
    - Lambert Point 107
    - Moore's Bridges 109
  - Comparison of records 113
  - Causes of mineralization 114
  - Freshening of deep water 114
  - Summary 116

UNDERGROUND WATER RESOURCES BY COUNTIES 117
- Accomac County 117
  - General description 117
  - Underground waters 117
    - Distribution and quality 117
    - Springs 118
    - Wells 118
  - Local supplies 119
    - New Church 119
    - Franklin City and Greenbackville 120
    - Chincoteague 121
    - Wells on the bay side at Saxis, Belinda, Marsh Market, and Grotons 122
    - Wells on the bay side farther south 123
    - Wells along the line of the New York, Philadelphia & Norfolk Railroad 129
    - Wells on the ocean side south of Chincoteague Bay 131
    - Wells on islands in Chesapeake Bay 131
    - Conclusions 133

- Alexandria County 133
  - General description 133
  - Underground waters 134
    - Occurrence and quality 134
    - Springs 134

PAGE
Hume 134
Erup mineral spring 135
Powhatan 135
Public supplies 137
Local supplies 137
Alexandria 137
Other localities 139
Conclusions 141
Caroline County 141
General description 141
Underground waters 142
Springs 142
Wells 142
Local supplies 142
Bowling Green 142
Other localities 143
Conclusions 144
Charles City County 145
General description 145
Underground waters 145
Occurrence and character 145
Springs 146
Wells 146
Local supplies 146
Conclusions 149
Chesterfield County 149
General description 149
Underground waters 149
Occurrence and character 149
Springs 150
Wells 157
Local supplies 157
Conclusions 158
Dinwiddie County 158
General description 158
Geology 158
Underground waters 158
Occurrence and character 158
Springs 159
Wells 159
Local supplies 159
Conclusions 159
Elizabeth City County 159
General description 159
Geology 160
Underground waters 160
Distribution and quality 160
Springs 160
Wells 160
Local supplies 160
Conclusions 163
Essex County 163
General description 163
Underground waters 163
Character and extent 163
Springs 164
Wells 165
Local supplies 165

PAGE
Conclusions 169
Fairfax County 169
General description 169
Underground waters 170
Occurrence and character 170
Springs 171
Wells 171
Local supplies 171
Conclusions 175
Gloucester County 175
General description 175
Geology 175
Underground waters 175
Distribution and quality 175
Springs 176
Wells 177
Local supplies 177
Conclusions 180
Greenesville County 181
General description 181
Geology 181
Underground waters 181
Distribution and quality 181
Local supplies 181
Hanover County 182
General description 182
Geology 182
Underground waters 183
Distribution and character 183
Springs 183
Local supplies 184
Conclusions 187
Henrico County 187
General description 187
Geology 187
Underground waters 188
Distribution and character 188
Springs 188
Wells 189
Local supplies 190
Conclusions 192
Isle of Wight County 192
General description 192
Geology 193
Underground waters 193
Distribution and quality 193
Springs 193
Wells 193
Local supplies 194
Flowing wells along James River 194
Flowing wells along Blackwater River 195
Conclusions 196
James City County 196
General description 196
Geology 196
Underground waters 197
Distribution and quality 197
Springs 197

PAGE
Wells 197
Local supplies 197
Conclusions 200
King and Queen County 200
General description 200
Geology 201
Underground waters 201
Distribution and quality 201
Springs 201
Wells 202
Local supplies 202
Conclusions 204
King George County 204
General description 204
Geology 204
Underground waters 205
Distribution and quality 205
Springs 205
Wells 205
Local supplies 205
Rappahannock River 205
Potomac River 206
Conclusions 207
King William County 208
General description 208
Topography 208
Geology 208
Underground waters 208
Distribution and quality 208
Springs 209
Wells 209
Local supplies 209
Conclusions 213
Lancaster County 213
General description 213
Geology 214
Underground waters 214
Distribution and quality 214
Springs 214
Wells 215
Local supplies 215
Conclusions 219
Mathews County 219
General description 219
Geology 220
Underground waters 220
Extent and character 220
Springs 220
Wells 221
Local supplies 221
Conclusions 222
Middlesex County 222
General description 222
Geology 223
Underground waters 223
Distribution and quality 223
Springs 223
Wells 224

PAGE
    Local supplies 224
        Conclusions 227
Nansemond County 227
        General description 227
        Geology 228
    Underground waters 228
        Extent and distribution 228
        Springs 228
        Wells 228
    Local supplies 229
        Deep wells north of Suffolk 230
        Conclusions 231
New Kent County 231
        General description 231
        Geology 232
    Underground waters 232
        Distribution and quality 232
        Springs 232
        Wells 233
    Local supplies 233
        Conclusions 235
Norfolk County 235
        General description 235
        Geology 235
    Underground waters 236
        Distribution and quality 236
        Springs 236
        Wells 237
    Local supplies 237
        Conclusions 243
Northampton County 243
        General description 243
        Geology 243
    Underground waters 243
        Distribution and quality 243
        Springs 244
        Wells 244
    Local supplies 244
        Conclusions 248
Northumberland County 249
        General description 249
        Geology 249
    Underground waters 249
        Distribution and quality 249
        Springs 249
        Wells 250
    Local supplies 250
        Conclusions 252
Prince George County 252
        General description 252
        Geology 252
    Underground waters 253
        Distribution and quality 253
        Springs 253
        Wells 254
    Local supplies 254
        Conclusions 255
Princess Anne County 256

PAGE
General description 256
Geology 256
Underground waters 256
Distribution and quality 256
Springs 257
Wells 257
Local supplies 257
Conclusions 259
Prince William County 260
General description 260
Geology 260
Underground waters 261
Local supplies 261
Richmond County 263
General description 263
Geology 263
Underground waters 263
Distribution and quality 263
Springs 263
Wells 263
Local supplies 264
Conclusions 266
Southampton County 267
General description 267
Geology 267
Underground waters 268
Distribution and quality 268
Springs 268
Wells 268
Local supplies 268
Conclusions 272
Spottsylvania County 272
General description 272
Underground waters 273
Distribution and quality 273
Springs 273
Wells 274
Conclusions 274
Stafford County 275
General description 275
Geology 275
Underground waters 275
Surry County 276
General description 276
Geology 276
Underground waters 276
Distribution and quality 276
Springs 277
Wells 278
Local supplies 278
Conclusions 280
Sussex County 281
General description 281
Geology 281
Underground waters 281
Distribution and quality 281
Springs 282
Wells 282

PAGE
Local supplies 282
Warwick County 284
General description 284
Geology 284
Underground waters 284
Distribution and quality 284
Springs 284
Wells 285
Local supplies 285
Conclusions 286
Westmoreland County 286
General description 286
Geology 287
Underground waters 287
Distribution and quality 287
Springs 288
Wells 288
Local supplies 288
Conclusions 292
York County 292
General description 292
Geology 292
Underground waters 293
Distribution and quality 293
Springs 293
Wells 293
Local supplies 293
Conclusions 294
Tabulated data regarding deep wells 295
Tables of analyses of spring and well waters 297

ILLUSTRATIONS

PLATE PAGE

I. Map of part of eastern Virginia showing flowing wells, and chlorine content of artesian waters in the Coastal Plain Province.........in pocket

FIGURE

1. Sketch map showing physiographic provinces of Virginia............. 6
2. Sketch map showing distribution of rainfall in eastern United States... 9
3. Diagrams illustrating types of Coastal Plain springs................ 45
4. Diagrams illustrating artesian conditions in the Coastal Plain Province of Virginia 52
5. Diagrams illustrating relation of head of artesian wells to topography in the Coastal Plain Province of Virginia......................... 52
6. Sections across Coastal Plain Province of Virginia showing geologic relations of artesian beds and of wells drawing on them.... (Facing) 58
7. Diagram showing artesian well relations at West Point............. 72
8. Diagram illustrating circulation of water in crystalline rocks, and well supply 84

TABLES

TABLE PAGE

1. Geologic relations and water supplies of Virginia Coastal Plain formations 20
2. Municipal water supplies in the Coastal Plain Province of Virginia.... 80
3. Details of deep wells in crystalline rocks.................. (Facing) 95
4. Analyses of well water from crystalline rocks....................... 95
5. Details of wells in the Coastal Plain Province of Virginia............ 298
6. Analyses and field assays of water from springs..................... 334
7. Analyses and field assays of well water from Columbia formations.... 338
8. Analyses and field assays of well water from Chesapeake formations.. 344
9. Analyses and field assays of well water from Pamunkey formations.... 348
10. Analyses and field assays of water from Upper Cretaceous formations.. 350
11. Analyses and field assays of well water from Potomac formations...... 352

LETTER OF TRANSMITTAL

VIRGINIA GEOLOGICAL SURVEY,
UNIVERSITY OF VIRGINIA,
CHARLOTTESVILLE, December, 1912.

*To His Excellency, Hon. Wm. Hodges Mann, Governor of
Virginia, and Chairman of the State Geological Commission.*

SIR:—I have the honor to transmit herewith for publication, as Bulletin No. V of the Virginia Geological Survey Series of Reports, a report on "The Underground Water Resources of the Coastal Plain Province of Virginia," by Mr. Samuel Sanford of the U. S. Geological Survey.

This report has been prepared by the Virginia Geological Survey in coöperation with the U. S. Geological Survey and should prove of much value to the Tidewater section of Virginia. It forms a companion volume to Bulletin No. IV, entitled "The Physiography and Geology of the Coastal Plain Province of Virginia," published by the Virginia Geological Survey in January, 1912.

Respectfully submitted,
THOMAS L. WATSON,
Director.

UNDERGROUND WATERS OF THE COASTAL PLAIN PROVINCE OF VIRGINIA

BY SAMUEL SANFORD.

INTRODUCTION

Scope of Report.—This report deals with an investigation of the underground waters of the Coastal Plain Province of Virginia, a tract of country some 9,500 square miles in extent, which roughly corresponds with what has been known since Colonial times as Tidewater Virginia. The purposes of the investigation were to continue the study, begun by Darton, of the artesian waters of the Coastal Plain, and to examine the waters obtainable by open wells. Thus this report covers the occurrence and character of both shallow and deep waters; the geological relations of water beds; extent of artesian horizons and areas in which flowing wells can be had; methods and costs of developing underground water supplies; special adaptability of waters for domestic or medicinal use, and their application in agricultural and other industries; the relation of well and spring waters to the public health with particular reference to water-borne diseases; in short, the report is intended to answer those questions relating to underground water that would be most likely to occur to any one interested in the subject, whether resident, homeseeker, or promoter of industrial enterprises.

The facts presented were collected through correspondence with postmasters, drillers, and well-owners, and through field work. The correspondence includes the data received in answer to circular letters sent out in 1905. The field work was done by the writer in 1906, 1909, and 1910, chiefly in the fall of 1906.

Acknowledgments.—The writer is under obligations to N. H. Darton, geologist, U. S. Geological Survey, for hitherto unpublished data relating to a number of wells mentioned in the text. Grateful acknowledgment is made of suggestions from M. L. Fuller, formerly geologist, U. S. Geological Survey, regarding particular questions that came up in the progress of field work; and to many well drillers, especially J. H. K. Shannahan, Easton, Md.; R. H, Milligan, Crisfield, Md.; O. D. Hale, Whealton, Va.; I. B. Clark, Accomac, Va.; L. Rude, Tilghman, Md.; S. H. Fetterholf, Achilles, Va.; H. E. Shimp, Cappahosic, Va.; J. W. T. Robertson, White Haven, Md.; and J. V. Bray, West Point, Va., for information regarding wells and the occurrence of artesian waters. Acknowledgment is also made to Froehling and Robertson of Richmond, Va.; W. H. Taylor of Richmond, Va.; the H. Bentley Smith Company of Philadelphia, Pa.; and the Sparrow's Point Boiler Company of Baltimore, Md., for kindly furnished copies of analyses of well waters. Many of the analyses were submitted to R. B. Dole and Chase Palmer of the U. S. Geological Survey, for recomputation to express results in the form adopted by the Federal Survey. Finally, the writer thanks the hundreds of persons who gave information regarding particular wells.

Literature.—Though many references to the wells and springs of Tidewater Virginia appear in narratives of travelers, in descriptions of various points of interest, and in accounts of military campaigns, the literature distinctly relating to underground waters is scanty, and is largely confined to the writings of Darton. His contributions comprise a paper before the American Institute of Mining Engineers,[a] a bulletin on Artesian Prospects in the Atlantic Coastal Plain,[b] and mention of underground waters in the Washington, Fredericksburg, Nomini, and Norfolk folios, Nos. 13, 23, 70, and 80, respectively, of the Geologic Atlas of the United States. By far the most important one of these is the bulletin on artesian prospects. It reviews the geologic relations of the water beds, contains a number of well records, many of which are reproduced in this report, and briefly indicates the outlook for artesian water in each of the Coastal Plain counties. Fuller and Darton[c] re-stated Darton's views in Water Supply Paper, No. 114, and Fuller summarized his own conclusions in a paper before the American Waterworks Association.[d] The conclusions of Darton and Fuller, chiefly those expressed by Darton in Bulletin No. 138 of the U. S. Geological Survey, have been briefly summarized by Watson[e] in a volume prepared for the Virgina Jamestown Exposition Commission.

The underground waters of the St. Mary's quadrangle, which includes a very small portion of Westmoreland County, are discussed by B. L. Miller in Folio No. 136 of the United States Geological Survey.

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[a] Darton, N. H., Artesian Well Prospects in Eastern Virginia, Maryland, and Delaware, Trans. Amer. Inst. Min. Engs., 1905, vol. 24, pp. 372-397.

[b] Darton, N. H., Artesian Well Prospects in the Atlantic Coastal Plain Region, Bull. U. S. Geol. Survey No. 138, 1896, pp. 162-190.

[c] Fuller, M. L., and Darton, N. H., Underground Waters of Eastern United States, U. S. Geol. Survey, Water Supply Paper No. 114, 1905, pp. 127-135.

[d] Fuller, M. L., Artesian Waters of the Atlantic Coastal Plain, Amer. W. W. Ass'n, 1907.

[e] Watson, T. L., Mineral Resources of Virginia, 1907, pp. 268-275.

The publications mentioned deal chiefly with geologic conditions and particularly with artesian water; references to the composition of the waters are largely limited to an occasional analysis. W. B. Rogers[a] in his report for 1835 gives an analysis of a spring at Williamsburg. In the Norfolk Folio, Darton gives analyses of the water from two flowing wells. Fontaine[b] has mentioned an alum spring near Fredericksburg. Peale, in Bulletin No. 32 of the U. S. Geological Survey, gives the anaylsis of a spring near Richmond. Haywood, in Bulletin No. 91 of the U. S. Bureau of Chemistry, gives a detailed analysis of a spring in Alexandria County. Froehling and Robertson[c] have published anaylses of five springs, two of which are mentioned by Watson in the report already cited; and Fuller, in his paper before the American Water Works Association, briefly refers to the quality of the water from different horizons, and the general character of the mineralization.

Nowhere, so far as the writer is aware, have the characteristic features of the artesian waters of most of the Virginia Coastal Plain been discussed at length.

Results of investigation.—The study of the Coastal Plain formations in Virginia, the examination of springs and wells, and the analyses of the waters, have shown that plenty of water is to be had, and except in a limited area in the southeastern and eastern part of the Coastal Plain artesian supplies of abundant flow and excellently adapted for domestic purposes can be obtained without difficulty. Enough deep wells have been sunk to prove the existence of several widely extending series of beds containing water-bearing sands, and it is possible to say at what depth, at most localities, a particular series of beds can be found.

Dug wells are so cheaply sunk that they have become the main source of domestic supply. Many such wells from their location and the insufficient precaution against the entrance of water contaminated by organic wastes may frequently become dangerous to the public health. But dug wells properly located and protected will, in many places, yield entirely satisfactory supplies. The deposits underlying the terraces on which stand many of the towns and villages of the Coastal Plain transmit water readily, hence springs issuing from such terraces or shallow wells in the villages are easily polluted by filth from vault privies and from cesspools.

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[a] Rogers, W. B., A reprint of Annual Reports and other papers on the Geology of the Virginias, 1884, p. 40.

[b] Fontaine, W. M., The Potomac Formation in Virginia. Bull. U. S. Geol. Survey No. 145, 1896, p. 68.

[c] Froehling, Henry, and Robertson, Andrew. A hand-book prepared for the Virginia Commission to the St. Louis Exposition, 1904, pp. 97-159.

The mineral content of the well and spring waters varies greatly at different localities, or even in the same locality, hence both the deep and the shallow waters are variously suitable for domestic use, boiler supply, or particular industries. The most striking characteristic of the artesian waters of certain formations on the west side of Chesapeake Bay is their relatively large content of sodium bicarbonate. In this aspect they differ from many deep waters.

TOPOGRAPHIC AND GEOLOGIC PROVINCES OF VIRGINIA

General statement.—The State of Virginia includes parts of three great topographic and geologic provinces which have been traced from New York to Georgia. In Virginia they are called the Allegheny Ridges, the Great Valley, the Blue Ridge region, the Piedmont Plateau, and the Coastal Plain. The approximate boundaries within the State of these provinces are indicated on the accompanying map. The two last are the only ones considered in this report. Because of the relations between these two provinces, certain features of the Piedmont Plateau are briefly mentioned here.

PIEDMONT PLATEAU

General description.—The Piedmont Plateau is a rolling plain that slopes gently eastward from the Blue Ridge mountains to where the hard rocks which underlie it are overlapped by the relatively unconsolidated deposits of the Coastal Plain. Where this plain now lies were once lofty hills and mountains, but weathering and the erosive action of the wind and the streams has reduced all great inequalities of surface. Since the deposition of the Coastal Plain sediments began, the area has been elevated, eroded, depressed and slightly tilted several times. It now stands higher than it did a geologically short time ago. The Piedmont rivers are actively deepening their channels, and are swift-flowing and unnavigable.

The rocks of the Piedmont Plateau comprise crystalline masses, granites, gneisses, and schists. The granites and some of the gneisses and schists crystallized from a molten state, but others of the gneisses and schists were once beds of sand and clay which after consolidating to hard rock lost all trace of original structure by mountain-building stresses in time long past. The ages of these rocks range from pre-Cambrian to Silurian. Among the crystalline masses are detached areas of comparatively little altered rocks, reddish, purplish and greenish sandstones, conglomerates and shales, intersected and parted by intrusions and flows of diabase, a heavy dark-greenish crystalline rock. These sedimentary beds and the diabase are of Triassic age, and the former belongs to the Newark series.

The eastward extent of the Piedmont rocks is unknown. They underlie the Coastal Plain and can be reached anywhere in Tidewater Virginia by wells of sufficient depth.

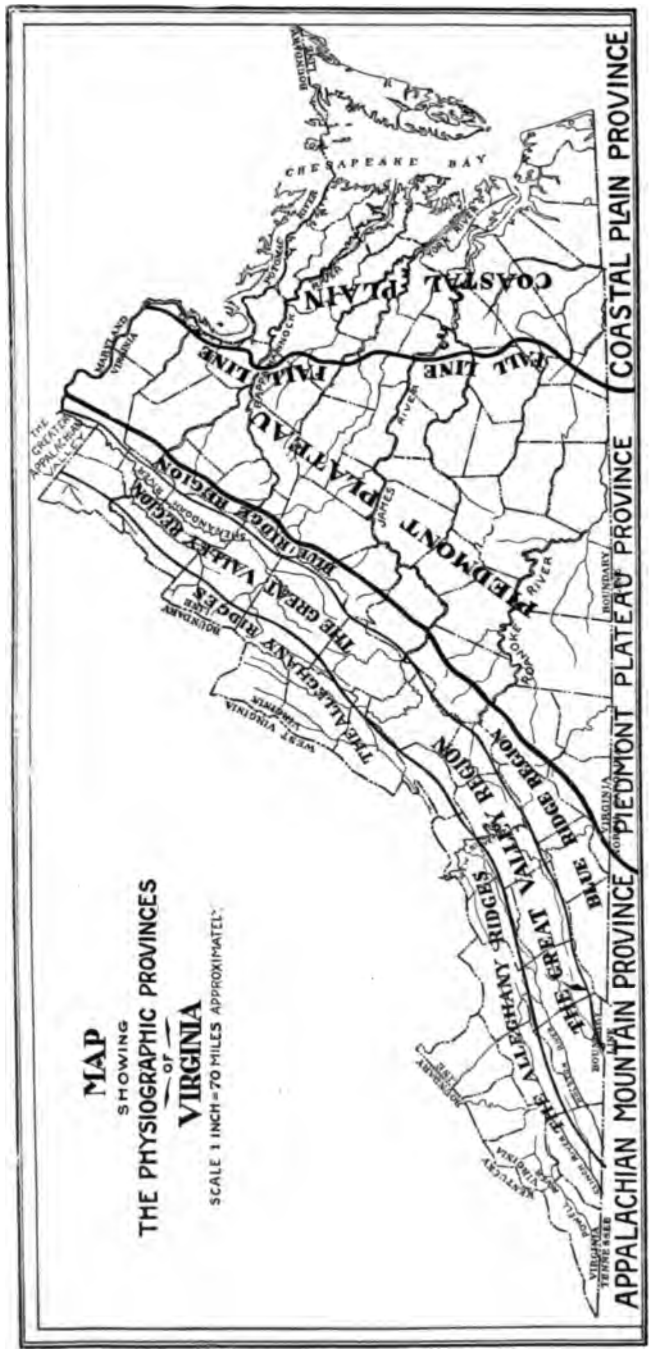

Fig. 1.—Sketch-map showing physiographic provinces of Virginia.
(After Watson, Mineral Resources of Virginia, 1907, p. 2.)

COASTAL PLAIN

General description.—Seaward from the Piedmont extends the lower-lying Coastal Plain characterized by its sluggish tidal rivers, stretches of flat land, and absence of hard rocks. Under the ocean the Coastal Plain beds reach the edge of the Continental shelf, a hundred miles off the Virginia coast.

Gravels, sands, clays, loams, and shell marls make up the great bulk of the Coastal Plain deposits in Virginia. In places some of the sands have been consolidated to sandstones and the clays to shales; in places, also, are shell beds so compact as to form lime rock, but there are no extensive areas of heavy-bedded limestones, such as are found in the Coastal Plain of North Carolina and of the states farther south. The "rocks" reported by drillers are mostly thin, irregular layers of limited extent. Some apparently are compacted shell beds but many are streaks or lumps of indurated sand in which the individual grains are cemented by silica or lime. The maximum thickness of the Coastal Plain formations in Virginia has not been determined. It may exceed 2,500 feet.

GEOGRAPHIC POSITION

The Coastal Plain of Virginia lies east of a line running through Emporia, Petersburg, Richmond, Fredericksburg and Alexandria, this line, from Emporia to north of Fredericksburg, corresponding nearly with the meridian of 77° 25'.. Its length from the North Carolina line to the Potomac River at Alexandria is 185 miles. The maximum width, from Assateague Island to west of Milford, is about 115 miles. The total area is about 9,500 square miles.

CLIMATE

The climate of Tidewater Virginia is mild; nearness to the ocean tends to temper extremes of heat and cold. The following table gives mean annual temperatures for varying terms of years at a number of places, together with the mean monthly maximum and minimum temperatures.

Temperatures in Tidewater Virginia.

(Degrees Fahrenheit.)

Place	No. years obs. made	Mean annual	Month of maximum	Month of minimum
Ashland	15	56.7	July 77.7	Jan. 35.3
Cape Henry	32	58.7	" 77.0	" 40.2
Fredericksburg	17	55.8	" 77.5	Feb. 33.3
Hampton	23	58.9	" 79.2	" 39.9
Norfolk	36	59.0	" 78.5	Jan. 41.1
Petersburg	19	57.9	" 77.7	" 37.6
Quantico	9	54.1	" 77.4	Feb. 28.6
Richmond	27	58.0	" 78.2	Jan. 38.0
Spottsville	18	57.3	" 77.9	" 37.8
Warsaw	....	....	" 78.0	....
Williamsburg	15	56.3	" 78.0	Feb. 34.6
Washington, D. C	36	56.3	" 77.3	Jan. 33.2

The climate is humid and the rainfall, which is so distributed through the year so as to favor the growth of vegetation, is abundant. The mean annual precipitation varies from 52 inches in the southeastern part of the province to 41 inches in the northwestern. The larger part of the precipitation is in the summer and spring, and comparatively little is in the form of snow.

The accompanying table shows the average precipitation at a number of places for various terms of years, and also the quarterly periods in which precipitation is greatest and least.

Precipitation in Tidewater Virginia.

Place	No. years obs. made	Mean annual	Mean quarterly maximum		Mean quarterly minimum	
		Inches	Quarter	Inches	Quarter	Inches
Ashland	15	41.75				
Cape Henry	32	52.34	Jul.-Sept.	15.72	Oct.-Dec.	11.21
Fredericksburg	15	42.25				
Hampton	23	43.60				
Norfolk	36	52.08	Jul.-Sept.	16.59	Oct.-Dec.	10.64
Petersburg	19	44.49				
Richmond	35	44.09	Jul.-Sept.	13.60	Oct.-Dec.	8.87
Spottsville	17	49.12				
Williamsburg	11	45.86				
Washington, D. C.	36	41.32	June-Aug.	12.57	Oct.-Dec.	9.36

A map (Chart 12) issued by the United States Weather Bureau from which the accompanying sketch map was made, shows how the rainfall diminishes in a northwest direction across Tidewater Virginia.

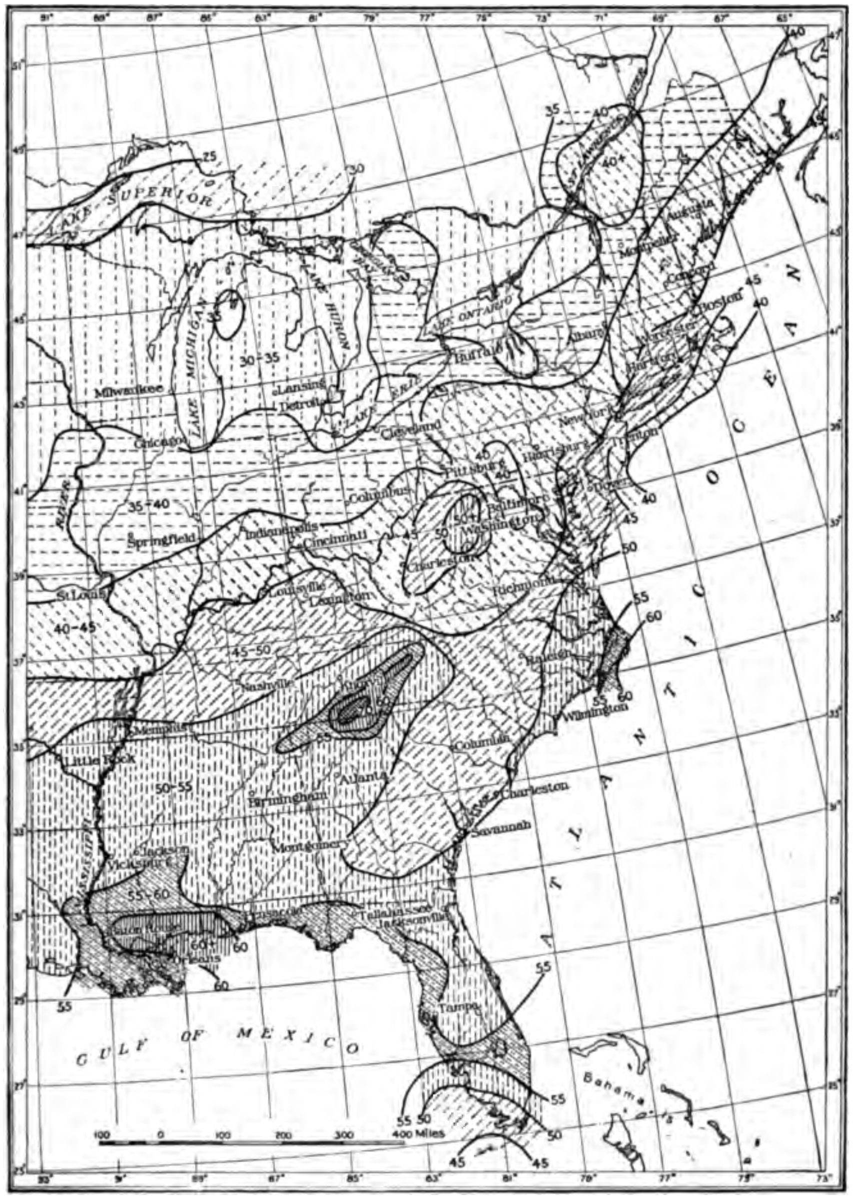

Fig. 2.—Sketch-map showing distribution of rainfall in eastern United States. (From U. S. Geol. Survey Water Supply Paper 223, p. 8.)

TOPOGRAPHY

General description.—The average seaward slope of the surface of the Coastal Plain of Virginia is about three feet to the mile. This slope is enough to cause rapid-flowing rivers, but the Coastal Plain rivers are sluggish because they flow through valleys that have been drowned by a recent depression of the land. Chesapeake Bay that crosses the eastern part of the plain from north-northwest to south-southeast is the drowned valley of a greater Susquehanna River that once flowed across the now submerged part of the plain to reach the ocean, then far east of the present shore line. Potomac, Rappahannock, and James rivers, the principal tributaries of Chesapeake Bay, are tidal estuaries to the western edge of the plain. Here the exposed crystalline rocks make rapids in the rivers; this zone of rapids has been called the "fall-line." Because sea-going vessels could not go farther inland, trading posts were established near the rapids on the different rivers in the early years of the colony, and these settlements have grown to the cities of Alexandria, Fredericksburg, Richmond, and Petersburg.

Terraces or terrace plains.—The seaward slope of the Coastal Plain, though gentle and as a whole uniform, is, in detail, step-like, broad terraces separated by more or less sharply defined scarps running along the river valleys and around intervening divides. The higher of these terraces or terrace plains, being oldest, are the more eroded; along river valleys and on narrow divides they have acquired a rolling surface and are sharply incised by the gorges of streams that head in springs or swamps. The lower and younger terraces have suffered less from stream attack. Near tide level in places the lowest terrace grades into salt marshes; inland in places it carries fresh water swamps, of which Dismal Swamp, lying on its widest portion, is the largest.

Topographic types.—Because of the varying elevation and width of these terraces and their manner of dissection, three types of topography may be distinguished in Tidewater Virginia. They are here designated as the eastern shore, the western shore, and the North Carolina.

The eastern shore topography is characterized by the low relief, under 50 feet, the slight erosion, and the gentle slope of the land toward tide level. Salt marshes fringe long stretches of the coast and tidal creeks reach inland up shallow channels.

The topography of the western shore is far more varied. Because of the narrow divides between the valleys of the Potomac, Rappahannock, York, and James rivers, and because along these rivers near the "fall-line" the highest of the terraces lies 200 to 400 feet above tide level, there are high cliffs and steep descents. The larger tributaries of the rivers have cut back into the divides. Their upper courses, locally called branches or runs, flow rapidly through narrow V-shaped valleys or shallow gorges, while the tidal lower courses, known as creeks, cross the youngest terrace by shallow partly drowned valleys. In places one terrace or another has been cut out by the rivers, so that here and there toward the fall line bluffs, or scarps, over 100 feet high mark the drop from a high terrace to tide level or the lowest terrace.

The part of the Coastal Plain south of James River has topography of the North Carolina type; that is, it resembles the topography of the northern portion of the North Carolina Coastal Plain. The stream valleys of the higher terraces are more open and have lower gradients than to the north; maximum elevations are less; the lower terraces are more extensive. The general slope of the surface is southeast and the rivers flow to the sounds of North Carolina. The above differences in topography determine differences in the occurrence of underground waters.

GEOLOGIC RELATIONS OF COASTAL PLAIN DEPOSITS

General description.—The generally unconsolidated deposits of the Virginia Coastal Plain rest on a floor of crystalline rocks that dips seaward. The beds just above bed-rock have an average inclination of about 30 feet to the mile; those laid down last dip 5 feet or less to the mile. Beds with steeper dips, 20° to 40°, have been noted in some of the formations, but such dips are local. The decrease in the dip from below upwards is a result of the initial seaward slope of the crystalline rocks and subsequent elevations and depressions. A succession of swings complicated by gentle bowings or warpings of the bed-rock has alternately carried the coast-line far to the eastward or brought it westward of its present position, so each great series or group of beds has been laid down on the beveled edges of the series below. As the tiltings have varied in direction, the overlap of one series has swung across the general strike of the beds in the preceding series, and as some formations overlapped unevenly eroded surfaces the boundaries on the west are quite irregular.

Thickness of deposits.—The maximum total thickness of the succession of formations is unknown. The deep well at Fort Monroe passed through 2,242 feet of beds; but the total thickness on the Eastern Shore is probably greater. At the big bend of Potomac River, northeast of Frederick the "fall-line"—the boundary between the Piedmont Plateau and C Plain—curves to the east and takes a north-northeast course Alexandria, Washington, and Baltimore. This may indicate a bow: the crystalline rocks into a broad trough having an axis that dips east. Hence it is possible that at Franklin City, a well would go tl 3,000 feet of sediments before reaching bed-rock.

CRYSTALLINE ROCKS

Character and extent.—The crystalline rocks along the westerr of the Coastal Plain comprise an extremely old (pre-Cambrian) sei gneisses, that originally were probably of igneous origin, intersect intrusions of later granite, and large masses of gneisses and schi doubtful origin, and age, though sedimentary in part and as late as Ordovician. These later gneisses and schists, like the older rocks, hav cut by igneous intrusions and the entire crystalline complex has b mashed by pressure metamorphism, that much of the original structu been obliterated and a complex system of folds and faults confuses of widely different age and origin.

Slightly altered Triassic sandstones and shales with associated sions and flows of diabase underlie the Coastal Plain near Doswe Ashland, but have not been found by deep borings elsewhere. This ever, is not surprising in view of the few holes sunk to bed-rock outsi immediate vicinity of Richmond and the probable limited extent Triassic rocks. The submerged portion of the Coastal Plain, which e 100 miles east of the present shore line, is presumably underlain by c line rocks like those above described.

Bed-rock topography.—The Piedmont Plateau once extended far its present boundary as an undulating plain, in which scattered hills sented rock-masses that had best withstood the wear of wind and rain. streams had reached their limit in down-cutting, and the bed-rock was mantled with the products of decay. By a seaward tilting in early ceous time, this mantle was worked over by streams and laid down a of sand, gravel, and clay. Since then earth movements have gently v the crystalline floor into broad open troughs in some of which the succ of sediments is hundreds of feet thicker than on the ridges be Hence, as the present rock-floor represents an original irregular roc face, modified by what bending has taken place since sedimentation depths to bed-rock vary at points equally distant from the "fall-line." The Fort Monroe record of 2,242 feet shows the average seaward slope between the well and the nearest point where crystalline rocks outcrop is 33 feet to the mile, but the slope is probably steepest near the "fall-line." North of Richmond, particularly along Potomac River, bed-rock slopes coastward at a greater rate, and a fall of 100 feet to the mile is indicated by the records of wells at Alexandria. This increase may mean that there has been faulting of the crystalline rocks near the "fall-line" north of Fredericksburg.[a]

WATER SUPPLIES

The crystalline rocks carry more or less water and along the western edge of the Coastal Plain deep wells have been drilled in them. The conditions governing the occurrence of water in crystalline rocks and in unconsolidated materials are so unlike, that the chief characteristics of the crystalline rocks as water bearers and the quality of their waters are discussed in a separate chapter (pages 83-97).

Although under special conditions water may travel through crystalline rocks for considerable distances, in general its circulation is limited. Where crystalline rocks are buried by water-filled porous beds, they contain, near the porous beds, water of the same general character as the latter. Hence it is not to be expected that wells sunk far east of the western margin of the Coastal Plain will obtain good water if the overlying unconsolidated beds carry water that is not potable.

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[a] Darton, N. H., Later Formations of Virginia and Maryland, Bull. Geol. Soc. Amer., vol. 2, p. 448.

SEDIMENTARY DEPOSITS

CRETACEOUS

LOWER CRETACEOUS

POTOMAC GROUP

Extent and character.—Immediately overlying the crystalline rocks throughout nearly all Tidewater Virginia is a great succession of gravels, cobble beds, sands, and clays classed as the Potomac group. This is exposed in stream gullies and railroad cuts along the western edge of the Coastal Plain from Alexandria to Fredericksburg, near Doswell, and in the valleys of James and Appomattox rivers south of Richmond and east of Petersburg. The smoothly rounded cobbles are of quartz, or dense vitreous quartzite, some dark, some light; cobbles of igneous rocks are rare. The sands frequently contain grains of feldspar, and where the feldspar grains are associated with angular quartz grains the sand becomes an arkose. The clays show great variety of color and texture. The proportion of coarse material is larger near the bottom of the succession of beds than near the top; also, the upper clays are often rather highly colored, red, yellow and brown, while those toward the bottom have more subdued tints, gray and dark green. The sands of the Potomac group, notably in exposures near Richmond and Petersburg, contain countless balls of clay that vary in diameter from an inch to a foot or more. They lie scattered through the sands and are even jumbled among hard quartzite boulders of equal diameter. Besides these balls the sands in places contain large sharply angular masses of clay that appear to have been torn from some bed. Sand and gravel beds compacted enough to make stone suitable for building rough walls are found on Aquia Creek and Appomattox River.

The Potomac beds show such local irregularities of dip that estimates of thickness based on dip can not be exact. It is probable that fully 350 feet of beds are exposed near Fredericksburg and at least 300 feet on Appomattox River. Under cover to the east, as shown by deep borings, the group thickens decidedly. The well at Fort Monroe went through 1,400 feet of material classed as Potomac by Darton.

The elevation of the lowest visible beds varies from sea-level at the "fall-line" to 250 feet in the divides between Potomac and Aquia creeks, Stafford County, and 300 feet on the hills northwest of Alexandria. The average eastward dip of the beds is from 30 to 60 feet to the mile.

The most striking characteristic of many Potomac outcrops is the heterogeneous mixture of materials. The sands are prevailingly cross-bedded; in places the minor beds are steeply inclined, but no bed is persistent for any great distance, and sections a few hundred feet apart in bluffs or railroad cuts show little correspondence. North of Fredericksburg and in the vicinity of Mount Vernon the upper part of the group is more evenly bedded.

Origin.—The fossils indicate that the Potomac beds as a whole were fresh water deposits and the varied aggregation of material in the lower beds shows that they were laid down by swiftly-moving currents. The fossils are mostly plant remains, impressions of leaves and seeds, with here and there lignitized or silicified wood. The animal remains include bones of dinosaurs.

DIVISIONS

The Potomac beds were first differentiated by W. B. Rogers[a] 70 years ago; he noted their composition and determined closely the boundaries of their outcrops. Since then they have been studied in greater or less detail by Fontaine, McGee, Ward, Darton, Clark, Bibbins, Miller, and Berry, and have been variously subdivided. Owing to the varying composition of the beds, distinctions based on lithologic character have proved unsatisfactory. On the basis of plant remains the Potomac in Virginia is divisible into two formations, an older and a younger. The older is known as the Patuxent and the younger as the Patapsco, from the typical exposures on Patuxent and Patapsco rivers in Maryland.[b]

Patuxent formation.—This, the lower of the formations, is traceable along river valleys near the "fall-line" from Alexandria to Petersburg. It comprises beds of cobbles, gravels and sands with discontinuous beds and lenses of clay and scattered clay balls. The sands are arkosic and cross-bedded. The clays are usually gray, drab, dark green, or chocolate in color. The fossils include plant remains of early Cretaceous types and bones of dinosaurs that have Jurassic affinities. The total thickness exposed north of Fredericksburg may be 250 feet. The formation dips east 30 to 60 feet to the mile.

Patapsco formation.—This formation has been recognized north of Fredericksburg and near Mount Vernon. South of Fredericksburg it is absent or is overlapped by Eocene and Miocene deposits. The Patapsco is clayey rather than sandy. The clays are bright-colored, and thicker and more evenly stratified than those in the Patuxent. The sands are less arkosic. The fossils comprise plant remains of Lower Cretaceous types. The exposed thickness of the Patapsco beds may be 150 feet. The formation dips east about 30 feet to the mile.

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[a] Rogers, W. B., The Geology of the Virginias.

[b] Clark, W. B., and Bibbins, A., Jour. Geol. 1897, vol. 5, pp. 479-506.

WATER SUPPLIES

Sandy beds in the lower formation of the Potomac group, the Patuxent, underlie almost all the Coastal Plain of Virginia and constitute vast reservoirs of water, but as they are deeply buried a short distance east of the "fall-line," making their development expensive, only a few wells draw on them. Most of these wells are near Alexandria. Near their outcrops the lower Potomac sands usually yield excellent water. Sands toward the top of the Patuxent seemingly are not so sure to yield good water. Far to the east the supplies become more mineralized and in the Norfolk area are too salty to be potable.

The significance of the disorder of the Patuxent sands to the well driller or geologist is that predictions of striking water at a given depth at a given place are little better than guess-work unless the records of near-by wells are known. Even then close estimates may be erroneous. Usually the best that can be done is to give the probable depth to a succession of sandy or gravelly beds, some one of which should carry satisfactory supplies.

UPPER CRETACEOUS

The Upper Cretaceous does not outcrop in Virginia. The outcrops of Coastal Plain deposits show a well-marked break above the highest beds of the Potomac group. Formations belonging to the Pamunkey (Eocene) and Chesapeake (Miocene) groups cut across the feather edges of the Potomac formations from the northeast. In Maryland and in North Carolina beds of Upper Cretaceous age, sands, clays, and greensands, intervene between the Lower Cretaceous and the Eocene deposits. As these beds have not been recognized in Virginia in wells less than 30 miles east of the "fall-line," their extent under cover in this State is conjectural. However, the Magothy formation is found on the heights back of Anacostia, D. C., across Potomac River from Alexandria, and the Raritan a few miles farther east. Upper Cretaceous beds were penetrated by deep wells at Crisfield, Md., Fort Monroe and Norfolk, Va. Back of Anacostia the Magothy may be 40 feet thick. Data for estimating the thickness of the Upper Cretaceous formations under cover far eastward are not particularly reliable. Darton thought there were 60 feet of Magothy and 35 feet of higher Cretaceous beds at Crisfield, Md., and 120 to 140 feet of "Marine Cretaceous" beds at Fort Monroe and Norfolk.

The Raritan formation of Maryland includes clays much like those of the Patapsco with interstratified sands. The Magothy is of more variable composition. The Upper Cretaceous material from the deep wells of Crisfield, Md., included greensands, fine gray micaceous sands, and dark clays. In the Norfolk-Fort Monroe area the Upper Cretaceous deposits comprise gray micaceous sands, dark gray, red and green clays, and gray sandy clays. Upper Cretaceous fossils have been found north of Fort Monroe by deep wells near Selden, Gloucester County, and Fairport, Northumberland County.

TERTIARY

EOCENE

PAMUNKEY GROUP

Extent and character.—Along Potomac River between Aquia Creek and Matthias Point; on the divide between Potomac and Rappahannock rivers; along the latter from 3 miles southeast of Fredericksburg to 4 miles east of Port Royal; on Mattaponi River above Marricossick Creek; on the Pamunkey from Hanover to Piping Tree Ferry; on James River from Richmond to Coggins Point; and on the Appomattox between Petersburg and City Point, are exposures of sands, sandy marls and clays that contain abundant marine fossils, mostly shells of mollusks. The clays below tide-level are prevailingly dark-colored, usually greenish, but one, exposed in outcrops north of Fredericksburg and found by artesian wells along Potomac and Rappahannock rivers, is reddish to white. The sands range in color from light gray through bluish and greenish shades to almost black; many are composed of quartz grains with a varied proportion of the small irregularly-rounded dark green or black nodules of the mineral glauconite, a silicate of potash and iron. When these glauconite grains predominate the material becomes a greensand or what well drillers term "black sand."

In the sands are indurated streaks or nodules that form dense hard rock; these streaks are of irregular thickness and small extent. There are also hard beds composed largely of shells. At the base of the Pamunkey is a thin but rather persistent bed of dark pebbles or small cobbles.

The contact between the Potomac and the Pamunkey near the "fall-line" in places is decidedly uneven. There is evidence near Richmond and

Petersburg, where there are inliers of Pamunkey among hills of Potomac material, that the Pamunkey was laid down on an irregularly eroded surface having almost as much relief as the present topography. The total thickness of the Pamunkey beds exposed on Potomac River is 225 feet. Unlike the Potomac group, the Pamunkey does not thicken greatly under cover, and it thins out to the southwest. The well as Crisfield, Md., penetrated possibly 150 feet of it; the borings at Fort Monroe and Norfolk not over 250 feet and possibly less than 100 feet. South of Petersburg to the North Carolina line there are no definitely identified exposures of Pamunkey beds.

Since deposition the Pamunkey beds have been slightly tilted and now dip 10 to 15 feet to the mile east. Above water-level, owing to the proportion of iron in the glauconite and the easy decay of the mineral, the Pamunkey sands weather to shades of brown, buff and yellow: the clays also grow brighter, buff being perhaps the color most frequently seen in high-lying exposures.

DIVISIONS

Clark, who has described the Pamunkey in Maryland and along Potomac River in Virginia, divides the group into two formations, the Aquia and the Nanjemoy, of which the Aquia contains the greater proportion of sandy beds and the Nanjemoy the more clay. For a detailed account of the Potomac River exposures the reader is referred to reports of the Maryland and Virginia Surveys.[a]

Aquia formation.—This formation is typically exposed along Aquia Creek in Stafford County, where it is 100 feet thick. It comprises beds of greensand and greensand marls containing many marine shells of Eocene age. Southward it thins out, is overlapped by the Nanjemoy, and is exposed in few Pamunkey outcrops south of Richmond.

Nanjemoy formation.—This formation, named after Nanjemoy Creek in Maryland, outcrops in river valleys from the big bend of Potomac River to Petersburg. It does not outcrop further south and at the North Carolina line its western boundary may be 30 miles east of Emporia. It comprises beds of sand, greensand and clay, with numerous marine shells. A distinctive bed of clay, white at the top, pink at the bottom, marks the base on the divide between Potomac and Rappahannock rivers near Fredericksburg, and has been recognized in wells along those rivers to the east. The total thickness of Nanjemoy beds exposed on Potomac River is about 125 feet.

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[a] Clark, W. B., Maryland Geol. Survey. Eocene. 1901. pp. 59-71; Clark, W. B., and Miller, B. L., Bull. No. iv. Virginia Geol. Survey. 1912. pp. 93-96.

Brief descriptions of the Pamunkey beds under cover, as reported by drillers, are shown in the well records published on succeeding pages.

WATER SUPPLIES

Under much of Tidewater Virginia the Pamunkey group is an important source of deep water, though the porous sands which give flowing wells are relatively thin and few in comparison to the total thickness of sandy material and the number of sand beds seen in the outcrops. The glauconite sands, because of the proportion of interstitial space between the rounded granules of glauconite, give up water more easily than quartz sands and such open-textured beds full of the dark green or black glauconite are called "water sands" or "true water sands" by well drillers.

MIOCENE

CHESAPEAKE GROUP

Extent and character.—The irregular edge of the Chesapeake cuts across the Potomac and Pamunkey beds in a south-southwest direction, and south of Rappahannock River to the North Carolina line the Potomac and Pamunkey are exposed only in river valleys. On the divides the western edge of the Chesapeake rests directly on the crystalline rocks. East of the line along which the Pamunkey beds slope below tide-level the Chesapeake deposits are hidden only by a thin covering of Columbia material and are exposed to river bluffs and in creek valleys nearly to Chesapeake Bay. Thus the area in which the Chesapeake outcrops is much greater than the combined outcrop areas of the Potomac and Pamunkey.

The Chesapeake beds are prevailingly sandy, with a varying proportion of clay. They comprise pure quartz sands, glauconitic sands, sandy clays, and beds of marl; the latter, full of tightly packed marine shells, are widely distributed. Some of the sand beds contain glauconite in scattered grains only, others are almost as glauconitic as those in the Pamunkey. Streaks and nodules of hard, cemented sand or "rock" occur at many horizons, but individually are of small extent. The colors below water-level are subdued, varying from light gray through bluish and greenish shades to dark greenish gray.

Near the base of the Chesapeake are drab and gray beds of clayey or finely sandy material full of the minute siliceous tests of diatoms, forming diatomaceous earth. In places, as just below Wilmont Landing on the Rappahannock, these diatomaceous earth deposits are 50 feet thick.

On exposure the Chesapeake beds weather to brighter tints, buff and yellow predominating. The elevation of the highest lying beds ranges from 250 feet back of Brooke, to about 100 feet near the Virginia-North Carolina line. The maximum thickness of the group in Virginia may be 700 feet. The dips are southeast and east, about 6 to 10 feet to the mile. In places comparatively steep reverse dips up to 30° are seen, but these are of small extent.

DIVISIONS

Four divisions of the Chesapeake, based chiefly on differences in the abundant marine fauna, have been recognized in Virginia by Clark; these are the Calvert, Choptank,[a] St. Mary's and Yorktown. This fourfold division of the Chesapeake applies to the outcrops west of the bay. The relation of the formations far under cover in the eastern and southeastern parts of the State has not been established. Deep wells near Norfolk show a great thickness of dark, fine sandy clays and clayey sands, and few distinctive fossils that might serve as guides in correlating records have been saved in drilling.

Calvert formation.—This formation, the most clayey of the four, has been traced along the west edge of the Coastal Plain from Potomac River to south of Petersburg. Farther south it is overlapped by the St. Mary's. It is well exposed at several localities, notably the bluffs on Rappahannock River south of Port Conway. It contains thick diatomaceous earth deposits and shell beds with characteristic marine fauna. The maximum thickness exposed is 200 feet. The average dip is southeast and east about 10 feet to the mile. It is named from Calvert County, Maryland.

Choptank formation.—This formation is sandier than the Calvert but contains a considerable proportion of clayey beds as well as diatomaceous earth. It is not exposed anywhere in Virginia but may intervene between the Calvert and St. Mary's under cover in the Potomac Valley as it has been recognized and mapped in Maryland.

St. Mary's formation.—This formation consists of bluish and greenish sandy clays and gray sand, with many thick beds of shell marl. It is established as a separate formation by the predominance of certain marine shells. The thickness is 150 feet and the dip 8 or 10 feet to the mile eastward. It is named from St. Mary's County, Maryland.

Yorktown formation.—This formation succeeds the St. Mary's so conformably that no sharp dividing line has been determined. It is sandy, richly fossiliferous, and at the type locality, Yorktown, contains firm, fairly hard rock made up almost entirely of comminuted shells. Its total thickness is over 100 feet. As a whole it slopes seaward at the rate of 6 or 8 feet to the mile, but in places are fairly steep westward dips.

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[a] Not recognized in Virginia by Clark and Miller, Bull. No. iv, Virginia Geol. Survey, 1912, p. 140.

WATER SUPPLIES

From its extent, stratigraphic position, and sandy character, the Chesapeake group is a notable source of artesian water. It has been tapped by many hundreds of inexpensive wells and its deep supplies, except on the eastern shore of Chesapeake Bay and in a few counties on the western shore, are soft, "light," fresh, and excellently suited to domestic use. The shallow waters may be hard from lying in beds of shells or iron-bearing from the decay of glauconite.

PLIOCENE (?)

No beds containing distinctive Pliocene fossils have been found in Tidewater Virginia. There are such beds in the Coastal Plain of North Carolina and of other states southward, notably Florida. The Lafayette has been classified as a Pliocene formation. The lithologic resemblances between the Lafayette and the Sunderland formation in Virginia are great and there is no definite proof that the Lafayette is older than Quaternary. It is here called Pliocene (?).

Lafayette Formation[a]

Extent and character.—The Lafayette is a far-extending but relatively thin mantle of clay, sand, and cobbles, in which the finer-textured material has in places an orange or reddish tinge. This vast, blanket-like deposit, usually gravelly toward the base but loamy near the surface, has been traced along the higher portions of the Atlantic Coastal Plain from New Jersey to Florida and across the Piedmont to the Blue Ridge. It is characterized not only by the bright hues of its loams and clays but by the peculiarly irregular and confused arrangement of the materials in many of the coarser beds. The formation is high-lying, overlapping the Coastal Plain sediments only where they are much above sea-level, and nowhere in Virginia reaching tidewater, being cut off seaward or riverward by distinct slopes and well-marked scarps. Another peculiarity is a scarcity of fossils, the organic remains being plant fragments and impressions of no determinative value. This far-spread mantle was first recognized as a distinct geologic unit by McGee[a] and named by him the Appomattox formation.

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[a] The name Lafayette was proposed by Hilgard in 1891 from Lafayette County, Miss. Amer. Geol. 1891, vol. 8, pp. 129-131. Berry has recently shown that the so-called Lafayette of the type section in Lafayette County, Miss., is of Eocene age. Jour. Geol. 1911, vol. 19, pp. 249-256.

The total extent of the formation in Virginia has not been determined. It covers little of the tidewater country. Its cobbles and gravels rest on the crystalline rocks of the Piedmont, or on the edges of Potomac, Pamunkey, or Chesapeake beds. Usually not over 50 feet thick and nowhere filling the gorges, the Lafayette caps the higher interstream plateaus. Its base is 480 feet above tide at Peach Grove Hill in Fairfax County, and 200 feet near Fredericksburg. Whether it actually is present at the type locality of McGee's Appomattox formation, southeast of Petersburg, is uncertain.[b]

Along Potomac River north of the great bend the Lafayette is sharply interrupted or cut off by the river valley. South of the great bend to Petersburg the eastern limit of the formation is less clearly defined, but probably nowhere extends far east of the "fall-line." It has been traced inland back of Fredericksburg for 10 miles, and has been described by Shaler and Woodworth[c] in the Richmond coal basin at altitudes of 350 feet.

Origin.—The probable origin of the Lafayette has caused much discussion. Some geologists have called it a marine formation, others have said it was formed by streams. Further investigation may show that the term Lafayette has been applied to both marine and fluviatile deposits. A detailed discussion of the origin lies without the province of this report. In Virginia the field relations, varied lithology, heterogeneous assortment of materials, and lack of fossils, are evidence in favor of a fluviatile or estuarine rather than a marine origin.

WATER SUPPLIES

The Lafayette gravels are reservoirs of ground water for springs and dug wells. The supplies they furnish are generally limpid and soft, and in some places remarkably low in mineral content but, from the limited extent of the Lafayette in the Coastal Plain, are important in only a few counties.

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[a] McGee, W. J., Three Formations of the Atlantic Slope, Amer. Jour. Sci. 3rd ser., 1888, vol. 25, pp. 120-143.

[b] The writer is of the opinion that the Appomattox formation in the vicinity of Petersburg, as described by McGee, includes Columbia beds, and that the Lafayette has not been differentiated with exactness there.

[c] Shaler, N. S., and Woodworth, J. B., Geology of the Richmond Basin, Virginia, 19th Ann. Rept. U. S. Geol. Survey, Part 2, pp. 385-519.

PLEISTOCENE

COLUMBIA GROUP

Character and extent.—Over most of Tidewater Virginia, resting on Miocene, Eocene, or Cretaceous deposits, or on the crystalline rocks of the Piedmont, lies a mantle of loam, clays, sands, gravels and cobbles; the older strata cropping out on river bluffs, in stream gullies, and on eroded divides. Like the Lafayette, this mantle shows a prevailing assortment into coarse material at the bottom and fine at the top, and its component beds show great differences of color, texture, and arrangement. The clays have many hues, from dark gray through yellow or buff to orange and red; the coarse material comprises evenly stratified sands and mixtures of sands, cobbles, and boulders that seemed dumped in place.

The Columbia differs from the Lafayette in several details. While the latter mantled an undulating surface, the Columbia partly filled river gorges and capped intervening divides. The Lafayette forms a sloping plain cut off to the seaward and along river valleys by scarps or graded slopes; the Columbia comprises several terraces or terrace plains that slope seaward and toward river valleys. Large transported boulders are not found in the Lafayette, but are common on the river terraces of the Columbia toward the "fall-line." Some of these boulders are seven or eight feet long, have polished and striated faces, and have evidently been dropped by ice floes. The Columbia loams on the lower terraces are mostly light buff and yellow; on the higher terraces, buff and red; but south of James River bright-colored loams are not so common as along Potomac River. Even on the highest terrace they are often light buff and yellow rather than dark buff, orange, and red.

The landward elevation of the surface of the highest terrace along the "fall-line" varies from 300 feet west of Alexandria to about 150 feet south of Petersburg. The surface of the lowest terrace is less than 25 feet above tide and extends to sea-level in many places. The only fossils found in the clays of the higher terrace are plant remains. The lowest terrace contains plant remains and marine shells.

DIVISIONS

In Maryland, three terraces were distinguished by Shattuck[a] and traced across the State. He found that while each terrace sloped seaward and toward river valleys, there was a remarkable uniformity of elevation at points on the same terrace many miles apart. The three terraces he named in order of age, from high to low, the Sunderland, Wicomico, and Talbot, and classified their materials as the Sunderland, Wicomico, and Talbot formations. This division of the Columbia he extended into Virginia.

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[a] Shattuck, G. B., The Pleistocene Problem of the North Atlantic Coastal Plain, Amer. Geol., 1901, vol. 28, pp. 87-107; Maryland Geol. Survey, Pliocene and Pleistocene, 1906, 291 pp. lxxv plates.

In North Carolina six terraces with elevations varying from sea-level to 200 feet have been described.[a] Stephenson[b] discriminates five Pleistocene terraces in North Carolina. The names he gives them and the elevations above sea-level are as follows, in order of age: Coharie, 160 to 220 feet; Sunderland, 110 to 160 feet; Wicomico, 60 to 90 feet; Chowan, 30 to 50 feet; Pamlico, 0 to 25 feet. The Coharie has not been recognized north of North Carolina. The Chowan and Pamlico together correspond to the Talbot of Maryland and Virginia as described by Shattuck.

Clark and Miller[c] have recognized and traced three Columbia terraces in the Virginia Coastal Plain and have designated as formations the deposits that constitute them, the Sunderland, the Wicomico, and the Talbot.

The terraces as a whole slope east or southeast, but along the rivers each terrace slopes toward the river; on the divides the slope is seaward. Hence the elevation of each terrace is least toward the river or the ocean and greatest at the foot of the slope or scarp which marks the transition to the terrace above.

In general there is on each terrace a rough assortment of materials from coarse at the base, to fine near the surface. The proportion of very coarse material, gravel, cobbles and boulders, is greatest near the "fall-line." The basal sands are generally gray in color; the tints of the subsoil loams and clays range from dark gray with bluish, brownish or greenish hues, to bright red, orange and buff.

The thickness of each terrace formation varies from a thin edge near the scarp above to a maximum at varying distances riverward or seaward. The maximum thickness of the lowest formation is uncertain because in places on the western shore of Chesapeake Bay and along the bay side and ocean side of the Eastern Shore, a considerable part of the formation lies below tide-level and its materials have not been definitely distinguished from the Chesapeake (Miocene) beds on which they presumably rest.

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[a] Johnson, B. L., Pleistocene terracing in the North Carolina Coastal Plain, Science, 1907, vol. xxvi, pp. 640-642.

[b] Stephenson, L. W., Geology and Underground Waters of the North Carolina Coastal Plain, N. C. Geol. Survey. In press.

[c] Clark, W. B., and Miller, B. L., Bull. No. iv, Virginia Geol. Survey, 1912, p. 48.

Sunderland formation.—Maximum elevations of the Sunderland range from 300 to 220 feet on divides back of the "fall-line," to 90 feet at points along the rivers farther east. The Sunderland-Wicomico scarp extends along a northeast line, that is a line at right angles to the trend of the larger river valleys. The materials of the Sunderland terrace, which constitute the Sunderland formation, comprise cobble-beds, sands and gravels, bright-colored loam and clays, and near the "fall-line," large boulders. The thickness of the formation varies from a feather-edge to a maximum of 50 feet.

Wicomico formation.—The Wicomico terrace can be traced at intervals along the rivers to the "fall-line" and around the intervening divides from North Carolina to Potomac River. It is widest south of James River where it is 10 miles wide. On the divides between York, James, Rappahannock, and Potomac rivers, this terrace is not as pronounced a topographic feature as the terrace below it. The terrace materials comprise cobbles, gravel, sand, and bright-colored loams and clays, much like the Sunderland. The thickness varies from a feather-edge to about 45 feet.

Talbot formation.—The Talbot is the youngest and most easily distinguished of all the terraces.[a] It is 30 miles wide at the south and includes all of Princess Anne County, most of Norfolk, nearly all of Elizabeth City County, the east end of Gloucester County, and practically all of Mathews County. Reëntrants of this terrace extend up the river valleys. On the eastern shore the terrace probably includes all of Northampton County and most of Accomac County. The Talbot formation is composed of sands, gravels, clays and loams, with cobbles and ice-borne boulders along the river toward the "fall-line." The fossils comprise cypress stumps and other plant remains, and beds of marine or brackish water shells. The thickness of the formation ranges from a few feet to fully 40 feet on the western shore of the bay. On the eastern shore the thickness may exceed 50 feet.

The relations of the Columbia terraces and the terrace materials to the underlying deposits are shown in Fig. 5, page 52.

Origin.—While a marine or estuarine origin for the terrace formations has been advocated, the question is still in dispute. The 0-25 foot terrace underlain by beds containing marine and brackish water-shells at Newport News, east of Norfolk, and in the Dismal Swamp area, is indisputably marine or estuarine.

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[a] The writer believes that the Talbot formation in Virginia, as described by Shattuck, comprises two formations; in other words, the Chowan and Pamlico formations of North Carolina extend into Virginia.

WATER SUPPLIES

The coarser beds of the several Columbia formations are important reservoirs of water in Tidewater Virginia, and are tapped by thousands of dug or driven wells. As the sands and gravels often rest on relatively impervious clayey beds of Miocene, Eocene, or Cretaceous age, and are exposed along scarps or in stream gullies, they are the source of countless springs. On the high terraces the ground water is mostly soft and of low mineral content. On the lower area and especially near tidewater it differs greatly; in most places it is limpid and soft and excellent for general use; here and there so mineralized as to be unfit for many purposes.

Undifferentiated Columbia Beds

Extent and character.—Beds of mud, sand, clay, and gravel underlie the lowest Columbia terrace, or the terrace now in process of formation, at places in the eastern part of Norfolk, Elizabeth City, Gloucester, Mathews and Princess Anne counties, and the whole Eastern Shore. The chief objections to including these beds in the Talbot formation are that their indicated thickness would make this formation much thicker than any of the older Columbia formations, and that there is nothing to show that all the beds accumulated while the Talbot terrace was forming. Some may antedate the Talbot terracing; some may even be of Pliocene age. In the localities mentioned the beds rest on Chesapeake sands and clays. As they do not outcrop but lie below tide-level they can be differentiated from the Chesapeake beds below and the Recent or Columbia beds above only by the study of well records and samples of drillings. As few samples have been saved the age remains in doubt.

These undifferentiated beds comprise soft, dark bluish or greenish and bluish-gray sands with rounded and sharply angular grains, and coarse gravel. Some of the beds contain many marine shells, some contain cypress stumps or logs.

The sands in which the shells lie, sparsely scattered or in distinct layers, are medium fine, and, when dry, light gray in color; when wet, dark bluish or greenish. They apparently form discontinuous bands or lenses of varying thickness, no single sand bed having been traced far. The sands are for the most part soft, and offer little resistance to the drill, but locally contain indurated streaks usually only a few inches thick that the drillers term rocks. The beds are separated by dark clays of bluish or greenish tinge, that vary in texture from tough and firm clay to soft mud in which the drill of a light jet rig will sink five or six feet in as many minutes.

The soft clays, those most frequently found, are described by drillers as "blue mud" or "blue marsh mud." The shell beds, logs and stumps found in these beds on the Eastern Shore all lie considerably below tide-level. The following list of localities and depths to shell beds nearest surface in Accomac and Northampton counties is given for its geologic interest:

List of localities and depths to shell beds nearest surface in Accomac County.

	Feet		*Feet*
Accomac	50	**Hunting Creek**	90
Belinda	80	**Mearsville**	117
Bloxom	83	**Mears Wharf**	75
Boggs	104	**Mappsville**	70
Cashville	100	**Mesongo Creek**	115
Chesconnessex	100	**Mt. Prosperity, near Onancock**	60
Craddocksville	140	**New Church**	120
Hallwood	110	**Pungoteague**	110
Harborton	126		

Northampton County: Charlton 63 feet, Upshur Neck 128 feet; throughout Northampton County generally, 60 to 90 feet.

A well near Onancock, sunk 110 feet, is reported by the driller to have struck a bed of "beach sand" containing small shells at 65 feet and to have been bottomed in shell-rock containing "oyster" and "clam" shells. "Pieces of bark and knots of wood" were reported between 60 and 100 feet.

Another driller, F. A. Merrill, of Onancock, reports striking in a well on Grapeland farm, on Occahonnock Creek, three quarters of a mile from Wardstown Post-office, a "stump" 70 feet below surface or 60 feet below tide-level. A well at the house of Tully Scott on Masitank Creek, three quarters of a mile west of Cashville, according to the owner, went through "pieces of wood" at 64 to 68 feet.

WATER SUPPLIES

On the Eastern Shore many flowing wells draw on these deep-lying Columbia sands. The heads are low and seem to be largely determined by local topography. Thus there are few flows along the bay shore near Saxis, Belinda, and Marsh Market in Accomac County where the Talbot terrace slopes gradually to the expanses of salt marsh that border the tidal inlets; the ground, as well drillers say, is "too low." But there are many flowing wells on the bay shore farther south, where, as about Onancock and Harborton, a terrace plain 15 to 20 feet high, often overlooks open water. Again there are more flowing wells in Accomac than in Northampton County where the general elevation of the surface is less than to the north.

It is not possible that the supplies of these Eastern Shore wells could have come from across the bay; the beds under the bay contain salt water at too great a depth to permit that. They are fed from ground water that is supplied by the rain and snow that fall on the Eastern Shore. The underground circulation is southward and from the higher land along the axis of the peninsula toward the bay and the ocean. The heads of the water in particular wells or groups of wells are closely related to the height above sea-level of the water table in the vicinity of the wells. Since the water beds lie comparatively near surface, are overlain by muds or soft clays and extend under tidal inlets, the flowing wells of the Eastern Shore all show tidal changes, but the lag is less than that of the deeper wells of the western shore.

No flowing wells that evidently draw on these sands have been reported in Mathews, Norfolk, and Princess Anne counties.

As the deep Columbia beds comprise both clean sands and swamp mucks the contained waters vary greatly. Some of the sands yield excellent water—clear, soft, and low in mineral content, while other beds yield waters that are highly colored, hard, contain iron and have a decided odor of sulphuretted hydrogen.

SUMMARY OF GEOLOGIC FORMATIONS AND THEIR WATER SUPPLIES.

The geologic relations of the various Coastal Plain formations, their constituent materials, and their importance as water-bearers are shown in the following table:

TABLE 1.—*Geologic relations and water supplies of Virginia Coastal Plain formations.*

System	Series	Group	Formation	Materials	
Quaternary	Recent	Columbia		Marsh and swamp muck, river silts and sands, beach and dune sands	(1)
	Pleistocene		Talbot	Sands and gravels, clays and loams, less brightly colored than those of older terraces, old cypress swamps and beds of marine shells; 0–40 feet	(2)
			Wicomico	Cross-bedded sands; cobble beds and ice-borne boulders toward "fall-line"; clays and loams often bright-colored, some plant remains; thickness 0–40 feet	(3)
			Sunderland	Cross-bedded sands; cobbles and boulders; bright-colored loams; thickness 0–50 feet	(4)
Tertiary	Pliocene (?)		Lafayette	Cross-bedded sands, locally indurated, cobbles, and small boulders; bright-colored loams and clays; thickness 0 to 50 feet	(5)
	Miocene	Chesapeake	Yorktown	Gray sands; beds of marine shells, locally indurated; thickness 0–150 feet	(6)
			St. Mary's	Gray bluish or greenish sands and sandy clays and shell marls, weathering to bright hues; thickness 0 to 250 feet	(7)
			Choptank (?)	Gray bluish and greenish sands, locally indurated, sandy clays and shell marls, not recognized in Virginia	(8)
			Calvert	Gray bluish and greenish sands, locally indurated, sandy clays and shell marls, thick beds of diatomaceous earth, weathers to bright hues; thickness 0–300 feet	(9)
	Eocene	Pamunkey	Nanjemoy	Gray and greenish sands, greensand marls, locally indurated, dark clays, shell beds, all weathering to bright hues; thickness 0–125 feet	(10)
			Aquia	Gray and greenish sands, greensand marls locally indurated, dark clays, shell beds, all weathering to bright hues; thickness in outcrops 0–100 feet	(11)
Cretaceous	Upper Cretaceous			Does not outcrop in Virginia, comprises, under cover, greensands, gray micaceous sands and dark clays; thickness uncertain, over 500 feet	(12)
	Lower Cretaceous	Potomac	Patapsco	Bright-colored, evenly bedded clays, dark clays, arkosic sands, plant remains; thickness in outcrops 0 to 150 feet	(13)
			Patuxent	Cross-bedded arkosic sands with pebbles and cobbles, in places sandstone, conglomerate and shale, clay beds and lenses, plant remains; thickness in outcrops 0 to 250 feet	(14)

WATER SUPPLIES

(1) Not important.

(2) Coarser beds supply ground water to springs and shallow wells; contain artesian water on Eastern Shore.

(3) Coarser beds supply springs and shallow wells.

(4) Coarser beds supply springs and shallow wells.

(5) Coarser beds supply springs and shallow wells.

(6) Ground water to springs and shallow wells, artesian water to a few wells.

(7) Ground water to springs and shallow wells, artesian water to many wells.

(8) May supply artesian water to a few wells.

(9) Ground water to springs and shallow wells, artesian water to many wells.

(10) Ground water to springs and shallow wells, artesian water to many wells.

(11) Ground water to springs and shallow wells north of Pamunkey River; artesian water to some wells.

(12) Artesian water of varying quality to a few deep wells near Chesapeake Bay.

(13) Ground water to springs and shallow wells, artesian water of varying quality to a few deep wells.

(14) Ground water to springs and shallow wells, artesian water of varying quality to a few wells near the "fall-line," and near Chesapeake Bay.

UNDERGROUND WATERS

ORIGIN, OCCURRENCE, AND DISTRIBUTION.

General statement.—Of the moisture that falls on the land in the form of rain and snow, part returns directly to the air by evaporation, part flows directly away by streams, and part enters the soil. The total precipitation on any region is distributed variously among these destinations, the exact amount that goes to any one being determined by factors which interact in an extremely complex manner.

Evaporation.—The proportion of rainfall that returns to the air by evaporation from the leaves of plants, before or after reaching the ground, or from the surface of the ground itself, varies greatly under different conditions. The temperature, the wind velocity, the character of the vegetation, the nature of the soil, all affect it. Evaporation is less in a cool climate with light winds than in a hot climate where fresh winds prevail. It is less from sandy than from clayey soils. It is less from fields than from forests. Tidewater Virginia has hot summers with liberal precipitation; on the other hand the wind velocity is low. Estimated on the basis of measurements at Washington, D. C., and including the water returned to the air by plants, evaporation in the Virginia Coastal Plain amounts to more than 50 per cent of the rainfall.

Run-off.—That portion of the rainfall that the streams carry away from a given district is the run-off. It includes the over-surface flow and the water from seeps and springs; it is determined by measuring the discharge of the streams, and is expressed either in inches, like rainfall, or as a percentage of the rainfall. The chief factors controlling run-off are vegetation and temperature. This is shown by Hoyt[a] who finds that while the winter run-off in Vermont is 92 per cent of the rainfall and in Virginia is 63 per cent, the summer run-off is practically the same in the two states. No determination of annual run-off in the Virginia Coastal Plain has been made but it is probably less than in the Piedmont counties of the State, where it is 40 per cent of the rainfall.

Controlling factors in soil absorption.—The chief factors regulating the entrance of water into the ground are the slope of the surface, the rate of precipitation, the air temperature, and the texture of the soil. On steep hillsides much rain water runs off before the soil can take it up; similarly, if the rain falls in a heavy shower less of it enters the soil than if it falls more slowly, because every soil has a certain rate of absorption, and if this be exceeded the excess water runs off. A high temperature decreases the surface tension of water so that water passes more readily through the soil pores. Sands have much larger pore spaces than clays, hence sandy soils take up water more rapidly than clayey soils.

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[a] Hoyt, J. C., Comparison between rainfall and run-off in the northeastern United States, Trans. Amer. Soc. Civ. Eng., vol. 59, pp. 431-520.

In the Virginia Coastal Plain the conditions favorable to the absorption of moisture reach a maximum on flat expanses of terraces with sandy soils during gentle rains in warm weather.

Storage capacity of soils.—The capacity of a soil to absorb water is a measure of its porosity. In sands, the evenness of size of the grains and their roundness of outline determine the proportion of voids, because if the grains are round the total amount of open space is independent of the diameter of the grains. A clean, evenly sized sand with well-rounded grains will absorb water equal to 40 per cent of its bulk; a cubic foot of such sand will absorb about 10 quarts. Sharp sands that pack closely and sands with grains of various sizes absorb less. On the other hand, loams have proportionally more pore space and greater absorption capacity. Some determinations made by King[a] showed that the percentage of pore space in clayey loams was about 44.5 per cent, and in sandy soils 30 to 35 per cent. Because of the great predominance of sands and sandy loams in the Virginia Coastal Plain, as shown in the table on page 29, it is probably safe to assume that the average absorption capacity of the soils is about 35 per cent.

SOILS AND SOIL SOLUTIONS.

Soils.—The soils of the Coastal Plain are derived almost wholly from unconsolidated beds of gravel, sand and clay, which in turn represent the washed-over debris of pre-existing unconsolidated beds, or the material worn from the hard rocks of the Piedmont Plateau. Since the Lafayette and Columbia formations lie blanket-like upon the older beds, and the latter are practically not exposed except where the Lafayette or Columbia beds have been removed by erosion, as on scarps, valley slopes, or narrow stream divides, the older beds are of less importance in the formation of soils. On the other hand the more or less weathered surfaces of the several Columbia formations form the cultivated soil of fully three-fourths of the Coastal Plain area.

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[a] King, F. H., Nineteenth Ann. Report, U. S. Geol. Survey, pt. ii, 1897-98, pp. 213-214.

On the basis of origin, soils may be divided into two classes, residual and transported. A residual soil represents what is left from the decay of rocks, and rests where it formed. A transported soil is composed of material that has been moved by water, ice or wind. Residual soils characterize the Piedmont Plateau, transported soils the Coastal Plain. In the latter province the great agent of transportation has been water. There has been movement as dust but not enough to be of much importance in soil formation. There are accumulations of wind-moved sands, or dunes, back of some Chesapeake Bay or ocean beaches, notably at Cape Henry, but these are of little or no agricultural value. The water-moved rock particles were variously transported, some by streams and some by the waves and currents of the ocean or tidal inlets; they were deposited along river bottoms or on flood plains, in swamps or shallow bays, or in the ocean. Thus the finest of silts and the coarsest of gravel were laid down simultaneously in the formation of any one of the Columbia terraces. The terraces have been variously eroded since elevation above sea-level. Certain areas in all the terraces have been better drained than others, and the rate of decay of the soil particles has therefore not been the same. In consequence of original differences in mode of deposition and in material, and of subsequent differences in erosion and weathering, the soils vary decidedly within short distances and show very complex relationships.

Soils may be classified not only by origin but by topographic features, depth, suitability for certain purposes, and by physical characteristics. The latter are the most obvious guides. They comprise texture, as shown by the proportion of mineral particles of different sizes, structure (the manner of arrangement of the particles), and color. These physical properties form the basis of soil classification adopted by the U. S. Bureau of Soils, but other factors are considered. A soil class is based on texture, as shown by a mechanical analysis. Soils of different classes that are evidently related in origin, topographic position, and color, constitute a soil series. The structure and color determine with what series a soil can be correlated. The unit of a soil series is the soil type and the type is established by considering the physical properties and all other determinable factors that have to do with the relations of soils to crops.

In the Coastal Plain of Virginia the U. S. Bureau of Soils has mapped about 940,000 acres, and has discriminated 24 soil types in this acreage. The areas occupied by these types are shown in the following table compiled from figures published in 1909.[a] The areas cover parts of Chesterfield and

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[a] Whitney, Milton, Soils of the United States, U. S. Bureau of Soils, Bull. 55, 1909, p. 233.

Hanover counties, all of Norfolk, Princess Anne and Warwick counties, and most of York and James City counties.

Area of soils surveyed in the Virginia Coastal Plain.

Name	Area of types in series	Total for series and types	Per cent. of total
	Acres	*Acres*	
Coastal beach	....	12,376	1.3
Chesterfield gravelly sandy loam	....	34,304	3.6
Chesterfield sandy loam	....	95,680	10.2
Elkton fine sandy loam	....	14,656	1.6
Leonardtown loam	....	43,584	4.7
Norfolk gravelly loam	1,344		
coarse sandy loam	4,288		
sand	11,200		
fine sand	20,864		
sandy loam	214,976		
fine sandy loam	230,272		
loam	23,872		
silt loam	5,952		
clay loam	1,856	514,624	54.8
Portsmouth sand	2,048		
sandy loam	50,048		
fine sandy loam	29,760		
silt loam	55,488		
clay loam	2,176	139,520	14.8
Swamp, tidal swamp and marsh	....	67,072	7.1
Wickham sand	4,416		
sandy loam	5,120		
loam	5,952		
clay loam	2,176	17,664	1.9
Total number of acres mapped		939,840	

The table brings out the relatively small extent of many of the soils, the predominance of two series, and the proportionally great extent of two types, the Norfolk sandy loam and the Norfolk fine sandy loam, which together occupy over 47 per cent of the area mapped. A survey of all the Virginia Coastal Plain might show soil types not as yet recognized there, and would change the present rank of some of the types, but would not alter the rank of the Norfolk series nor of its two predominating types—chiefly because these types occupy areas on both high and low terraces, whereas the topographic distribution of the other types as a rule is more restricted.

For a description of the soils named in the preceding table and their suitability for particular crops the reader is referred to the government bulletins from which the tables were compiled. The Norfolk soil series is described as consisting of light-colored sandy soils underlain by yellow or orange sand or sandy subsoils, while the Portsmouth is characterized by dark gray to black surface soils underlain by yellow, gray or mottled yellow and gray subsoils.

As has been stated, the texture of a soil is determined by the proportion of the different sized mineral particles in it that are found by mechanical analysis. The U. S. Bureau of Soils recognizes seven grades, the limits of which are arbitrarily fixed. The texture of the Norfolk soil series is shown by the following table:

Textures of Norfolk soils.[a]

Name	Fine gravel (2–1 mm.)	Coarse sand (1–0.5 mm.)	Medium sand (0.5–0.25 mm.)	Fine sand (0.25–0.1 mm.)	Very fine sand (0.1–0.05 mm.)	Silt (0.05–0.005 mm.)	Clay (.005 mm. or less).
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Norfolk gravelly loam....							
soil	5	13	12	17	18	25	9
subsoil	3	9	11	14	18	27	17
Norfolk coarse sandy loam							
soil	9	24	14	10	10	22	9
subsoil	11	38	20	11	4	9	5
Norfolk sand							
soil	3	15	22	38	10	8	4
subsoil	3	16	21	37	9	8	5
Norfolk fine sand.........							
soil	0	3	10	56	14	11	5
subsoil	0	2	9	53	16	14	5
Norfolk sandy loam......							
soil	4	5	14	31	18	11	7
subsoil	4	12	10	22	12	12	26
Norfolk fine sandy loam...							
soil	1	3	5	38	24	22	8
subsoil	1	3	4	20	17	21	24
Norfolk loam							
soil	1	6	9	24	17	30	11
subsoil	1	6	9	20	15	29	19
Norfolk silt loam							
soil	1	3	4	10	14	54	12
subsoil	0	3	4	9	13	51	19
Norfolk clay loam.......							
soil	1	3	8	23	7	34	23
subsoil	0	4	6	18	7	32	33

[a] U. S. Dept. Agriculture, Bureau of Soils, Soil Survey Field Book, 1906, pp. 47-54.

Soil solutions.—The solubility of the mineral compounds in the soil, under local conditions of rainfall, temperature and drainage, and the chemical reactions which take place in the underground circulation determine the quality of the ground water. The Coastal Plain soils, deep as well as surficial deposits being included under this term, comprise sands, loams, clays, shell beds, and beds full of glauconite. The sand grains are composed chiefly of silica, but in some formations many sand grains are made up of compounds of silica, alumina, iron, lime, potash, and soda. The ease with which these compounds are dissolved is determined not only by the solubility of the compounds but by the fineness of the soil particles, hence the quality of the ground water, that is, the kind and degree of its mineralization, varies decidedly from place to place.

In general the reason for the variations is easily recognized; lime carbonate is readily dissolved, hence shell beds contain limy, or "hard," water. Many iron compounds dissolve without difficulty, and iron-bearing solutions precipitate iron on exposure to air or by mingling with oxygen-bearing waters. Thus along the western edge of the Coastal Plain the loams that contain grains of iron sulphide worn from the Piedmont rocks are the source of "iron" and "alum" and "sulphur" springs and seeps; beds of bog-iron form where such waters accumulate on the surface, and iron crusts and bands grow along the underground water courses. Hydrogen sulphide, the compound which gives so many Coastal Plain waters a "swampy" or "marshy" odor, is derived not only from the dissolving of iron sulphide but from compounds found in the organic matter contained in many Coastal Plain beds; it may also come from reaction between sulphate of lime, a common constituent of soils, and other compounds.

Although as above indicated the mineralization of a particular water may be from causes easily recognized or self-evident, the quality of another water may be due to reactions that cannot be definitely traced, or to long-past events in the geologic history of the region. Instances of these differences are the high percentage of bicarbonate of soda in many Coastal Plain waters and the saltness of others; in the one case we have to deal with a matter little understood, the selective interactions between certain mineral solutions underground; in the other with sea water which was originally in the beds or reached them after deposition.

GROUND WATER

Definition of ground water.—Of the water that enters the soil some is returned to the air through the capillary action of the soil particles and evaporation, some is absorbed by plant roots, stored in tissues, and ultimately returned by plant decay, or is given back to the air by transpiration from foliage; a little is taken up by the hydration or weathering of rock particles in the soil, and some reaches the ground water. By ground water is meant the water beneath the surface at any given point; its lateral extent and depth below surface are determined by several factors. Its lower limit may be at dense, impervious beds or there may be no sharp lower limit, the water filling crevices in rocks to an indefinite depth.

Water table.—The upper surface of the ground water is called the water table; it marks the water level in wells. Its depth below ground depends on topography, geology, and climate. In general the water table rises under hills and falls toward valleys. Under a level plain with soil of uniform texture, bounded by descents to lower ground, the convexity of the water table as a whole depends primarily on the texture of the soil and the difference in elevation between the plain and the lower ground. But the water table slope is modified by differences in soil texture, in the character and position of underlying rocks, in surface slope and in vegetation. It lies nearer the surface in fine textured soils than in coarse, and nearer under tilled fields than under forests. Where the water table cuts the surface of the slope there are seeps and springs; where confined hollows descend below the water table there are ponds. Under a flat expanse on a high terrace the water table may be at the surface, whereas near the scarp of that terrace it may be 50 feet below the surface of the ground.

Fluctuations of water table.—The water table rises after wet weather and falls after droughts, but these changes are not sudden. It takes a sensible period for the soil to absorb and transmit rainfall, so the water in wells may be low during a rainy period, in consequence of preceding drought, and may remain high long after rains have ceased. The seasonal differences in the height of the water table are the result of accumulative differences in the proportion of rainfall that reaches the ground, so that the period of lowest or highest ground water lags after the period of most or least rainfall, subject to superimposed modifications from evaporation and the growth of vegetation.

In Virginia the ground water is highest in the spring and lowest in the fall. These fluctuations are greater away from ravines and scarps than near them, because the water under a level stretch remote from any point of emergence moves very slowly and a rise in the water table of several feet increases the general slope toward the point of emergence but slightly, whereas near a scarp the water can run away so fast that the water table rises very little.

Besides being affected by the seasonal differences in rainfall, the water table is affected by other factors. Fluctuations in atmospheric pressure are among these. A rise of one inch shown by the barometer means an increase in air pressure equal to a foot of water. This load transmitted underground by wells can depress the well water by forcing it back into the sand and locally raising the water table. In the course of the field work for this report one instance of a dug well showing the effect of changes in air pressure was noted. This well, 26 feet deep, is near Potomac Mills, in Westmoreland County. The normal depth of the water in dry weather is about 2 feet. When the wind during such weather blows from the northwest, that is when the barometer is high, and the atmospheric pressure is heavier than the average, the level of the water in the well falls. With wind from the southeast, that is when atmospheric pressure is less, the water rises.

In very shallow wells changes in air temperature affect the surface tension of water. Cold increases the surface tension, hence if some of the ground water is near enough to surface (within a few feet) to feel the change, it rises into the partly saturated soil above the water table under the capillary attraction of the soil particles, thus lowering the level of the water in wells.

Change of level, due to natural or artificial causes, in nearby bodies of surface water—rivers, lakes, or the sea—may affect the water table decidedly. Where there is communication between such a body of water and nearby ground water, either through rock crevices or the pores between sand grains, a rise of the surface water raises the water table, either by direct transmission or by backing up the outward flowing ground water. Along Chesapeake Bay many shallow wells show tidal changes. These changes are not instantaneous since transmission through sands implies time, and along tidal bodies of water high water in a well occurs after high tide. The time difference or lag is governed by distance from shoreline and ease of communication below ground. It may amount to several hours.

Perched ground water.—Some accumulations of ground water are purely local. A sheet of clay may separate saturated sands from dry sands below, resulting in what is known as perched ground water. Such a condition may be found at many places in Tidewater Virginia, and is especially noticeable after prolonged wet weather. Boring a hole through the clay draws off the perched water. In this way some ponds or swamps may be drained.

Circulation of ground water.—Two factors, gravity and capillarity, control the movement of underground water. Downward percolation, as the drainage of a soil after a rain, is largely due to gravity and takes place chiefly through the larger openings in the soil. On the other hand the water evaporated from a soil is supplied from below either by the capillary movement through the finer openings or by the creeping of thin films of water around the soil particles. Gravity and capillarity act together where the movement is downward or are opposed when the movement is upward. They combine to bring water to the surface on a slope.

The texture of the soil determines the relative efficiency of the two factors, because the soil openings are many times larger in coarse sands than in silts or clays. Practically, the water returned to the air by plants as well as that evaporated from the surface of the soil is supplied by capillary action, whereas the water of springs and wells is supplied by gravity. The relative importance of gravity and capillarity in the movement of ground water is nearly equal, the proportion of the rainfall that ultimately reaches the surface again under capillary action, being little less than the proportion of gravitational or drainage water returned by springs.

The movement of gravitational water toward some point of escape is modified by differences in soil texture, the position and character of the rocks below the soil, and the slope of the surface. By reason of the variety of factors the course of a drop of water toward some spring may be changed from a straight line many times.

In granites and other dense igneous rocks, circulation is by joint cracks of which there are usually three systems, one parallel to the surface, the other two steeply inclined. In stratified rocks, circulation is of two orders. In sandstones and conglomerates there may be both direct movement along the bedding through openings between constituent grains, and cross circulation through joint cracks. In shales, circulation is practically limited to joint cracks and bedding planes. In limestone, as the rock is readily dissolved, openings of considerable size may grow along bedding planes or cross fissures and may become large enough to take the entire volume of small rivers. The freedom of movement through sandstones and conglomerates is seldom comparable to that through sands and gravels, because of many original voids being closed by the cement that binds the grains and pebbles.

Rate of movement of underground water.—In fine sands with rounded grains the openings between the grains are of capillary size, and the frictional resistance to the movement of water is great; in sharp sands that pack closely the resistance is still greater. In coarse sands the voids are many times larger than in fine sands and the water can move with much more freedom. Ease of transmission through a soil thus depends on the size, shape and evenness of assortment of the soil particles, there being all gradations between coarse gravel and clay. A coarse sand transmits water 100 times as freely as a fine sand. A clay absorbs water but its transmission capacity is practically zero.

In discussing the capacity of soils to transmit water, Schlichter[a] says:

> If the particles of sand or gravel which make up the water-bearing medium are well rounded in form, the pores are somewhat triangular in cross section and the diameter of the individual pores is only one-fourth to one-seventh the diameter of the soil particles themselves. Thus if the individual grains of sand average one millimeter in diameter the pores through which the water must pass will average only one-fourth to one-seventh of a millimeter in diameter. If to a mass of nearly uniform sand particles larger particles be added the effect on the resistance to the flow of water will be one of two kinds, depending principally upon the ratio which the size of the particles added bears to the average size of grains in the original sand. If the particles added are only slightly larger than the original sand grain the effect is to increase the capacity of the sand to transmit water, and the more particles of this kind are added the greater will be the menace in the capacity of the sand to transmit water. If, however, larger particles are added the effect is the reverse. If particles seven to ten times the diameter of the original sand grains be added, each of the new particles tends to block the passage of the water. Thus, for example, a large boulder placed in a mass of fine sand will tend to block the passage of the water. As more and more of the large particles are added to a mass of uniform sand, the rate of flow of water through it will be decreased until the amount of the large particles equals about 30 per cent. of the total mass. From this time on the adding of the large particles will increase the capacity of the whole to transmit water until, if a very large quantity of the large particles be added, so that the original mass of fine particles becomes relatively negligible, the capacity to transmit will approach that of the mass of the large particles alone. These facts have an important bearing upon the capacity of gravels to furnish water to wells or to transmit water in the underflow of a river. The presence of large particles is not necessarily to be interpreted as indicating a high transmission capacity of the material, for this is indicated only when the large particles constitute a large fractional per cent of the total mass, as would be the case where the large particles equal 40 or 50 per cent of the whole.

The rate at which water moves underground is controlled by the resistance of the soil openings and by the slope or difference in height between two given points in its course. Through such mixtures of sand, gravel and boulders in nearly flat beds as lie in the terraces of the Virginia Coastal Plain, the rate is to be measured by feet a day rather than by miles a day, as in a surface stream. On the south shore of Long Island are Coastal Plain beds resembling in texture and inclination some of those underlying terraces in Virginia. Velocities have been measured there that range from 15 inches to 12 feet a day.[a]

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[a] Schlichter, C. S., Field measurements of the rate of movement of underground waters, U. S. Geol. Survey. Water Supply Paper No. 140, 1905, p. 10.

Underground lakes and rivers.—The belief held by many persons that underground waters in places outside of limestone regions lie in lakes or move as rivers, has little foundation in fact. The lakes and streams reported by well drillers are merely beds of saturated sand. The rivers described with great particularity by some water finders often are pure fiction, the stated course of an underground river having no relation whatever to the geology of the district.

Ground water temperature.—Soils absorb and radiate heat readily but transmit it slowly, so that daily temperature fluctuations are felt only a very few feet underground; even the changes from summer to winter become imperceptible at less than 100 feet, and the unvarying temperature there corresponds very closely to that of the mean annual temperature of the particular locality. Several factors combine to determine the distance below surface of this zone of unvarying temperature. In Tidewater Virginia it apparently lies at about 60 feet. Thus the temperature of shallow wells or springs varies seasonably, that of deep wells is constant. At depths of 20 to 40 feet, depths equal to those of the average dug well in the Tidewater region, the cumulative results of the winter's cold and the summer's warmth are minimum temperature in the spring and maximum temperature in the fall, but the difference between maximum and minimum is slight. In shallow, open wells the temperature of the water may be modified by heat taken from or given to the air, and changed decidedly by the entrance of water from near the surface after heavy rains, but allowing for these contingencies, there is no ground for the belief of many a well-owner that the water from his well is cold in summer and warm in winter; a thermometer will show him his error.

Chemical composition of ground water.—Rain that falls at the end of a shower is practically pure water. In passing through the soil the rainwater takes up carbon dioxide gas and also various salts. It attacks and slowly breaks down the resistant particles of the hardest rocks, reduces dense granite to grains of quartz and particles of clay, and completely dissolves beds of shells.

The chemical composition of the ground water at any point is determined by the rainfall, the drainage, the climate, and the composition of the soil. Where precipitation is as abundant as in Tidewater Virginia and underground circulation is active, the soil at a certain point may be leached of easily soluble compounds in a time geologically brief; the ground water will thereafter have little solid matter in solution and will be soft and limpid. On the other hand, if the circulation is difficult the leaching will be less, and the mineralization of the water will persist for a longer period.

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[a] Schlichter, C. S., Op. cit. p. 67.

The soils of the higher terraces of the Coastal Plain of Virginia usually contain near scarps waters of extremely low mineral content; on the lower terraces the waters in places carry considerable iron or lime; on the lowest terrace, near the bay, where broad expanses of ground are covered by salt water during high spring tides, the ground water in places is distinctly brackish.

Few complete analyses of waters from dug wells are available, and the field assays presented in table 7 do not show the wide variety in quality of the waters. The analyses of spring waters (table 7) show the low mineralization of the waters from the sands of the high terraces.

Normal chlorine.—Chlorine, a constituent of common salt, is found in all surface and underground waters. It is derived from the sea as salt spray borne inland with dust particles by the wind and precipitated in rains, from the soil minerals, and from organic wastes. Hence the chlorine content of surface waters, other conditions not being considered, is greatest near the seashore and diminishes inland. The spring waters in table 7 show as a rule this chlorine decrease. In a given region the proportion of chlorine in the surface waters derived from soil minerals and from the sea is called the normal chlorine content of the waters. Any increase above the normal represents drainage from habitations, since the density of population on a given area has a direct bearing on the proportion of chlorine contained in the water flowing from that area. Hence, chlorine above normal in a surface water is taken as evidence that the water is or has been polluted.

Owing to variations in freedom of circulation and the composition of the soil, the normal chlorine content of the underground waters of a given region varies within wide limits, and a chlorine content above the normal of the surface waters does not necessarily denote pollution. A notable chlorine content in the waters from springs and shallow wells on high ground may indicate that the waters have been polluted, but many shallow wells near seashore tap waters that are normally brackish. High chlorine in the waters from a deep-drilled well is not necessarily evidence of pollution. In the water from a pumped well it may or may not be suspicious. Increase of chlorine in wells near the sea is not uncommon under heavy pumping.

Pollution of ground water.—Decaying organic matter carried in solution from the surface to the ground-water zone may make the water of wells or springs in the vicinity highly colored and offensive. Such discolored, ill-smelling water is rightfully viewed with suspicion, but a water that is clear, colorless or odorless may be much more dangerous. The menace to health is not the organic compounds in the water, but the microscopically small bacteria that cause specific diseases. These pathogenic germs may or may not be found in clear, refreshing spring waters having a local reputation for healthfulness or for curative properties.

A sanitary analysis of a ground water shows the proportion of compounds presumably of organic origin—nitrates, nitrites, and ammonia—and the proportion of chlorine. The proportion of organic compounds and of chlorine is taken to indicate the probable sanitary quality of the water. The value of such an analysis is disputed by many chemists.[a] In Tidewater Virginia the almost universal use of wood-curbing in dug wells, the practice of dosing such wells with lime and salt after cleaning, and the large variations in chlorine content of the ground water at places on the shores of inlets, combine to make the value of a sanitary analysis even more doubtful than for surface waters unless the chemist knows the local conditions. A bacterial examination of a suspicious water may be decisive, but in most cases no examination or analysis of a water is necessary to show its doubtful purity. A glance at the well surroundings, the nearby privy, pig-pen or slop-hole, or the leaky curbing that permits any kind of filth to be washed in at every rain, will suffice to show why the well water is to be regarded with suspicion.

Areal extent of pollution.—In sedimentary deposits like those of the Virginia Coastal Plain, the decaying organic matter and the disease-spreading bacteria that reach the ground water are carried along its upper surface toward the nearest point of escape. The distance they may travel before they are destroyed by filtration and oxidation depends on the rate of movement of the water table and the fineness of the sands. Some recent experiments in Germany[b] showed that heavy pumping could make bacteria from a polluted well 177 feet deep pass through 69 feet of sand and gravel (porosity 32 per cent) to an unpolluted well of equai depth in nine days; whereas if the bacteria were forced into the soil above ground water-level no pollution could be detected after prolonged pumping.

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[a] Leighton, M. O., The futility of a sanitary water analysis as a test of potability; Biological studies by the pupils of Wm. Thompson Sedgwick, Boston, 1906, pp. 36-53.

[b] Experiments on the passage of bacteria through soil. Engineering Record. 1909, Nov. 4, vol. 60.

Where, as on many terraces of the Coastal Plain, coarse sand and gravel or shell marls underlie a few feet of surface loam, and the water moves with comparative freedom toward springs that flow from the terraces, conditions are particularly favorable to the spread of pollution underground. Any shallow well or any spring in the village may come under suspicion. Where waters from a possible source of pollution must pass through 10 feet or more of loam and sand to reach the ground-water zone the danger is lessened, but in general the radius of safety between well and source of pollution is not less than 100 feet. A dug well and a vault privy within the limits of the average 25-foot building lot favor a quick transfer of water from the well to the house and back to the well, but a more unsanitary arrangement can hardly be devised.

EMERGENCE OF GROUND WATER.

Seeps.—A large proportion of the ground water is returned to the surface or escapes below water level by seepage. Seeps make wet and boggy spots on slopes or at the base of scarps, and supply imperceptibly much ground water to bodies of surface water. Seeps differ from springs in size and localization of flow. Springs mark the escape of ground water moving in a definite passage through the open-textured portions of a porous bed or along crevices and solution passages in hard rocks. In other words, a spring is seepage water emerging in sufficient volume at one point to form a rill. No sharp dividing line separates seeps and springs; the gradation in volume and localization of flow is gradual. Many so-called springs in Tidewater Virginia are basins or shallow wells fed by seeps.

Springs.—Speaking of the tidewater country in general, Hugh Jones,[a] an Englishman who visited Virginia early in the eighteenth century, said: "good springs abound everywhere almost." This statement holds true. Because of the liberal rainfall, the bedding of the Lafayette and Columbia sands, the manner in which pervious overlie less pervious deposits, and the many places at which the water table is exposed on bluffs and slopes or in gullies, springs of excellent water abound in most of the Coastal Plain counties. They are most numerous in the counties near the "fall-line." There are few where the surface is low and little eroded, as in Norfolk, Princess Anne, Mathews, Accomac and Northampton counties.

Because of its composition, extent, position, and great dissection, the Sunderland formation is the source of a majority of the springs.

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[a] Jones, Hugh, The present state of Virginia, London, 1724; reprint, New York, 1865, p. 57.

TYPES OF COASTAL PLAIN SPRINGS.

Few of the Coastal Plain springs gush from rock crevices like the springs of the Piedmont region, or issue as giant flows from large cavities, like the springs of the limestone regions of the Great Valley. Instead the waters gently flow from the sands along terrace scarps or in ravines, and the volumes are small. In places where hollows in the surface of an impervious stratum, a bed of clay, a band of iron crusts, collect the water from a considerable area are springs of larger size. In places also springs of good size flow from open-textured beds of shell marl. Three types of springs are distinguishable. They may be termed normal, perched, and artesian or boiling springs, and their characteristics are shown in Fig. 3.

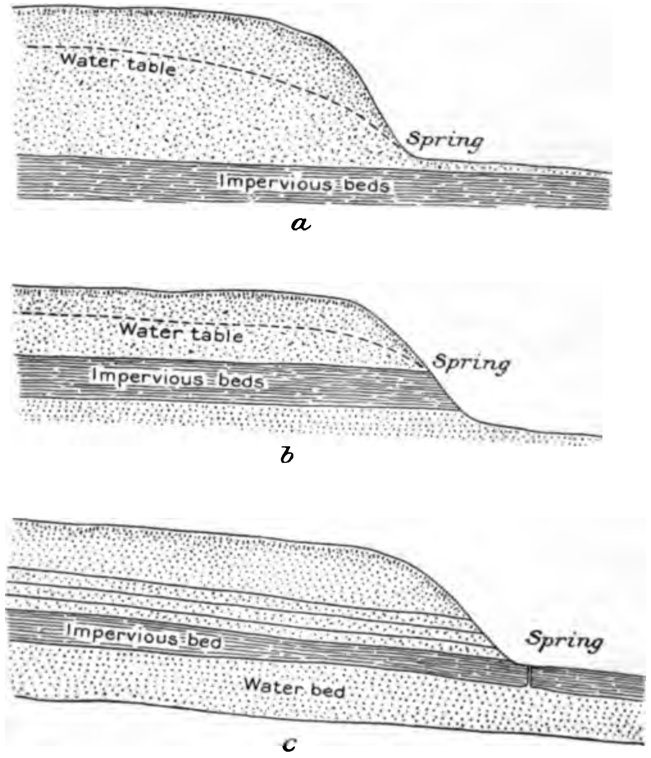

Fig. 3.—Diagrams illustrating types of Coastal Plain springs. (*a*) Normal spring. (*b*) Perched spring. (*c*) Artesian spring.

Normal springs.—Springs of the normal type are those that issue where the water table is exposed at ground-level. They are found in hollows on terraces along the bases of scarps, and on low terraces. Hence they are common to all parts of the Coastal Plain and flow from all the formations exposed. Many are of shallow source and go dry every year.

Perched springs.—This name has been proposed by Matson[a] for springs from perched ground-water, those that issue from above some impervious layer exposed in a stream gully or terrace scarp. The point of emergence may be 100 feet or more above the foot of the bluff, or the point at which the top of the main ground water supplies springs of the normal type. Perched springs are characteristic of that part of the Virginia Coastal Plain having topography of the western shore type—interstream divides sharply cut by V-shaped valleys of creeks, high scarps facing rivers—this area lying between Potomac River and the divide separating the Chesapeake from the Chowan drainage. Thousands of them issue from the base of the Columbia formations above sandy clays of the Chesapeake and Pamunkey groups.

Artesian springs.—While the waters usually seep or flow from a slope, the face of a bluff or the side of a gully, in places there are springs that are slightly artesian, the waters rising with force enough to lift sand grains in the spring basin. Such are known as boiling springs. As a rule the impervious layer from under which the waters rise is less than 10 feet below the spring basin and at some springs is covered only by a thin wash of sand. In places the source is deeper.

SOURCES OF SPRING WATERS

In general the springs are fed by the rainfall on the particular terrace from under which they flow. As the terraces are cut up by stream valleys and the ground water takes the easiest course to its point of escape, in the majority of cases the water does not travel more than a mile or two underground, and in many places springs of some size flow from a narrow remnant of a Columbia terrace capping a divide, where the gathering area is less than a quarter of a mile wide.

The temperature of the spring waters shows that the springs are fed by the ground water of the terrace rather than from deep sources. Most "cold" springs have a temperature of about 58 to 60 degrees, or the mean annual temperature of the region. These "cold" springs flow from beds buried 50 feet or more. Springs which show higher temperatures than the annual mean do not have this temperature the year round. The water gets warmer in summer because of the shallow cover of the source. No spring in Tidewater Virginia, so far as known, has throughout the year a temperature above normal, as have the deep flowing wells, and evidently no spring freely rises from a depth of several hundred feet. Those that are coldest in the fall have the deepest source, and this source is not deep enough to show the increase of temperature due to depth.

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[a] Matson, G. C., Water Resources of the Blue-grass Region, Kentucky, Water Supply Paper, U. S. Geol. Survey, No. 223, 1909, p. 40.

PERMANENCE OF FLOW

Many springs in the Coastal Plain fail in every dry summer. Many yield less water after several months of drought, and many show slight difference in volume. These differences represent differences in the magnitude of the fluctuations of the water table.

Near the edges of high terraces wells go deep for water, and the height of the water in the wells changes but little during the year; springs flowing from the scarps of these terraces have much more uniform flow than those in hollows on terraces away from scarps, where wells are shallow and are full in the spring and dry in the fall. Still there are springs having immediate shallow sources that flow the year through with little reported change in volume. Some such springs evidently are supplied by water that comes through a confined channel so small in proportion to its length that fluctuations of ground water level are minimized. Springs flowing from crevices in granite in hollows of high terraces are of this class, other springs which show little change in volume though having apparently shallow covers are fed by the water that comes from under a terrace above the one that seems to supply them.

PURITY OF SUPPLY.

Pollution of spring sources.—As most of the Coastal Plain springs flow from sandy beds covered by loams, surface waters undergo filtration in reaching the ground-water zone and in traveling to the point of emergence. Hence as a rule the springs of the Coastal Plain, if properly developed, are not likely to be the source of disease. On the other hand, where cities or villages stand on terraces having a thin cover of loams and coarse sands below, the ground water is easily contaminated by leakage from cesspools or sewers, or the impurities washed into dug wells, and springs flowing from the scarps of such terraces may be altogether unsafe no matter how clear, sparkling and refreshing their waters are.

Quality of spring waters.—The quality of the spring waters varies widely. As a rule the waters from the Columbia sands of the higher terraces are soft, contain little iron, and are suited for all domestic purposes. Springs from the lower terraces show greater differences. Many "marl springs" that flow from shell-marl beds in the Pamunkey or Chesapeake group, yield hard water. Here and there, particularly along the western edge of the Coastal Plain, are small springs whose waters contain sulphates of iron and alumina.

The analyses in table 6 show the characteristic differences in mineralization of the springs flowing from sands, from granite, and from marl, and the modifications resulting from topographic position. The granite, and the sand and gravel springs of Alexandria and Chesterfield counties contain less than 100 parts per 1,000,000 of total solids, and many are extremely soft, some containing less than 1 part per 1,000,000 of calcium. They are also low in chlorine. Evidently the sources of mineralization of the granite and the slightly mineralized sand springs are approximately the same, being derived from well-leached or relatively insoluble soils. On the other hand, the marl springs and the springs in low terraces near Chesapeake Bay show as a rule more total solids, more lime, and more chlorine. The most heavily mineralized waters in the table are those from two marl springs, one in Surry County and one in Sussex County.

DEEP AND ARTESIAN WATERS.

Function of ground water.—The greater part of the ground water in Tidewater Virginia does not rest on a clearly defined impervious floor, but lies above more or less pervious rock or unconsolidated material and there is no sharp line of demarcation between the ground water and what may be called, for convenience, deep or artesian water. Where, as in the Piedmont province, there is a mantle of rotted rock and residual soil, or where, as in the Coastal Plain, there are blanket-like formations of unconsolidated material, it is often convenient to take the top of solid rock or of beds older than those lying at the surface as the base of the ground-water zone and to regard the surface material as constituting a great sponge, its function being to absorb and store precipitation and slowly feed ground water to crevices and porous beds in the underlying formations.

Deep circulation.—Circulation below, as in the ground-water zone, is determined chiefly by gravity, but although in a general way influenced by topography, it is closely controlled by geologic structure. The porosity of the beds, their dip, the size and extent of cracks or fissures, are more important than topographic differences. So while the ground water flows down a valley, the deep water may move in a direction at right angles to the valley's trend.

The deep circulation may extend to far greater depth at one place than at another. Thus, where porous beds are steeply inclined or the continuity of rock masses is broken by profound fissures, water may circulate thousands of feet below the surface. On the other hand, where thick flat beds of shale lie near the surface there may be little or no deep water, as in certain regions of Pennsylvania and adjacent states.

While primarily governed by gravity, deep circulation may be assisted by the increase of temperature with depth; the waters from the surface working downward reach higher and higher temperatures until, through some comparatively free way of ascent, they rise and emerge at the surface as thermal springs. Also, deep waters may become so charged with gases that they rise more strongly than by difference of level alone.

In the Coastal Plain of Virginia deep circulation is along gently inclined porous strata and neither gain in temperature nor gaseous content is an important factor in the movement of the water. Flow down hill is sufficient to account for the facts observed. Yet, while the water moves down the dip of the porous beds toward the sea, the course of a single drop may be anything but a straight line. The beds are not of uniform texture for long distances. Instead, the water-bearing sands form irregular partly connected or discontinuous lenses, here coarse, here fine, and a drop following the line of least resistance may move down, across or even up the general dip of the beds. The limiting depth of active circulation is unknown, but the high mineralization of the deep waters in the Norfolk region indicates that their circulation is feeble.

Temperatures of deep water.—The thermal gradient, or rate of increase of temperature with depth, varies from place to place being most rapid in regions of recent volcanic activity. Unless running freely through open passages, underground water has the temperature of the material in which it is found. Hence temperatures of a large number of wells of varying depth show the temperature of the line of no change, its distance below the surface, and the increase of temperature with depth beneath.

Some observations in Tidewater Virginia indicate that the mean temperature of the line of no change is 56° to 59° and that the line lies at least 50 feet below surface; its exact depth was not determined because of the difficulty of getting the temperature of the water in the relatively small number of wells 50 to 100 feet deep.

Temperatures of flowing wells measured at the surface are subject to error. In most of the older artesian wells in Tidewater Virginia casing goes only to some dense bed below the Columbia sands and gravels. In some areas, as at West Point, two or even three deep water beds have been penetrated, and the flows from all the sources mingle, so that the temperature at a certain well is not the temperature of any one flow. Again in rising through several hundred feet of pipe water loses heat. Hence of two wells side by side tapping the same water bed, the one poorly sunk or cased that yields a mere dribble will show a decidedly lower temperature than its freely-flowing neighbor; for the same reason the flow of a 6-inch well will show the temperature of the source more accurately than that of a 2-inch well.

Temperatures of a considerable number of flows were taken in the course of field work, as shown in table 6. These temperatures are subject to the possible errors above stated, the most trustworthy figures being those of the freest flows.

In the following table are grouped the depth and temperature of flow of a number of wells:

Temperatures of artesian flows in Virginia Coastal Plain.

Location	Depth	Flow	Temperature of flow	Probable mean ann. temp. of locality
	(Feet)	*(gal. per min.)*	(°F)	(°F)
Mount Holly	153	15	63	
Chain Ferry	172	10	62	
Warsaw	188	16	62.5	
Coan	188	16	62.5	
Tappahannock	256	5.5	62.5	56
Boulevard	266	52	63	57.5
Jamestown	270 (6-inch well)	40	65	56.5
Bayport	300	20	64	56.8
Jamestown	300 (3-inch well)	78	64	56.5
Freeport	330	2	63	
West Point	335	37	66	
Curtis Point	361	2	67	56.6
Leehall	400	2	65	56.4
Urbanna	476	25	68	56.8
Irvington	580		69	56.3
Lamberts Point	616	51	72	59
Selden	716	52	70	57

The indicated average gradient of 1° for each 40 feet increase in depth is probably a close approximation to the truth.

The above table subject to the errors indicated may be used for roughly checking the depth of a well. For instance, the water from the bottom of a well 300 feet deep should have a temperature of about 64° F. This check however is of no value unless an accurate instrument is used. Many cheap thermometers are not correct within 2 degrees, and to use one of these is a waste of time.

Composition of deep water.—The substances in solution in the deep water at a given point necessarily bear some relation to the composition of the enclosing beds, to the depth below surface, and to the freedom of movement, but this relation is often extremely obscure. The chemical reactions that take place, under the conditions of circulation in solutions as dilute as most underground waters, are hardly comparable with the reactions observed in a chemical laboratory.

In Tidewater Virginia the mineralization of the deep waters increases toward the southeast. This change is not directly due to increase of depth, nor has it been shown to be due to changes in the composition of the enclosing beds. The rank of the controlling factors is discussed in the consideration of the artesian flows of the Norfolk-Newport News area. Defective circulation seems most important.

ARTESIAN WATERS

Definition of artesian.—The term artesian well has different meanings in different parts of the United States, being applied variously to all bored or drilled wells much deeper than the dug wells of the particular locality, to deep wells in which the waters rise, and to wells in which the waters rise and overflow. Even in Tidewater Virginia usage is not uniform. Both the deep drilled wells with water-level 100 feet below surface, at Richmond, and the much shallower flowing wells along river banks or the shores of Chesapeake Bay are called artesian. In this report the word artesian is used to designate the hydrostatic principle, the tendency of water to seek its level. Hence artesian waters are those which rise when the beds containing them are tapped. An artesian slope is a slope with artesian water below it, and an artesian well is one that taps artesian water. A well in which the water rises above ground-level is called a flowing well.

Artesian conditions.—Flat-lying ground water obviously cannot be artesian; the water in a well sunk to it will stand at the level of the water table. Difference of elevation is essential, the other conditions vary from place to place.[a]

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[a] For a discussion of all the factors involved, see Summary of the Controlling Factors of Artesian Flows, by M. L. Fuller, U. S. Geol. Survey. Bull. 319, 1908, 44 pp.

In Tidewater Virginia the governing conditions are these:

(1) Sufficient rainfall.
(2) Porous beds that receive rainfall directly or indirectly.
(3) Differences of elevation.
(4) Sufficient slope to the porous beds to carry them below less pervious beds.

Coastal Plain an artesian slope.—The Coastal Plain formations dip seaward. They contain water-filled open-textured beds overlain by relatively dense beds. The confined waters are artesian, and the Coastal Plain is an artesian slope. Some conditions causing artesian water are indicated in Fig. 4.

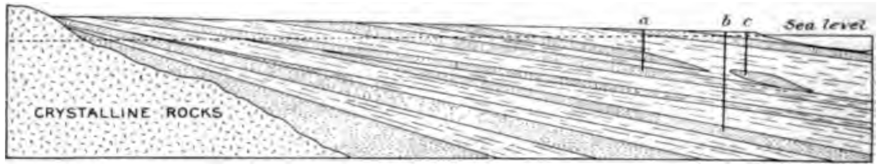

Fig. 4.—Diagram illustrating artesian conditions in the Coastal Plain Province of Virginia. (*a*) Well penetrating two artesian sands; strong flows because of sands pinching out or becoming clayey. (*b*) Well finding no water in beds penetrated by (*a*), but drawing on a water bed that does not outcrop. (*c*) Well to isolated sand bed, water under low head.

Source of artesian water.—To account for flowing wells some persons assume a great difference of elevation is necessary and say of the water gushing from a bore hole that it must "come from the mountains." They do not realize that there is no difference in principle between water rising in a well to 10 feet above the water bed and water rising to surface, nor do they realize that the heads of the flowing wells are low in comparison with the elevation of hills not far distant. The water that gushes from a well in Tidewater Virginia either entered the artesian bed at its outcrop or was fed to it from overlying beds. In either case the water entered the ground within the Coastal Plain. Some topographic relations of the artesian flows are shown in Fig 5.

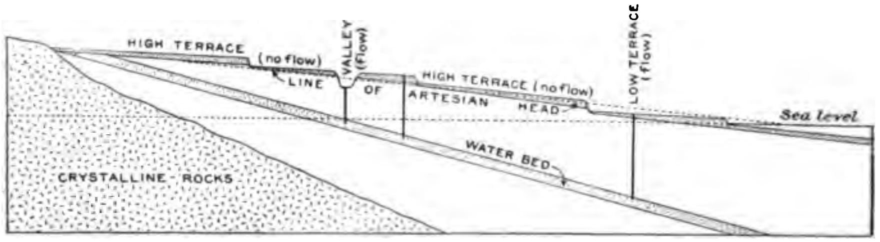

Fig. 5.—Diagram illustrating relations of head of artesian wells to topography in the Coastal Plain Province of Virginia.

Initial head.—As the Potomac, Rappahannock, Pamunkey, Mattaponi, and James rivers have cut valleys to the western edge of the Coastal Plain, the outcrops of beds or zones that carry artesian water to the east are exposed from tide-level almost to the tops of the interstream divides. Hence what may be called the initial head of the waters is not represented by the elevation of the porous beds at their edges on the divides nor by the height of the water table in deposits overlying the upper edges of the beds, for there is leakage toward the valleys.

Loss of head.—Ordinarily water never rises as high in a well as the level of the ground water supply of the artesian bed. This loss of pressure is due to the frictional resistance the water has met in passing through the sands, and to leakage in the journey to the well or down the dip of the beds beyond the well. Where water is confined under pressure in a widely-extending bed of uniform size sand grains through which the movement of water in any given direction is very slow, the flow to a well is along the bed from all directions at practically the same velocity, and the loss of head by frictional resistance during transmission from the distant source is small. Thus in that vast artesian reservoir of the Great Plains—the Dakota sandstone—the loss of head down the dip is only about 1 foot per mile. Water in beds of sand less evenly sized or less confined shows much greater loss of head, 100 feet per mile or even more.

In the Coastal Plain of Virginia are artesian sands in which the size, the angularity, the evenness of assortment, and the looseness of the component grains vary greatly, hence water circulates through them at various rates. On this account, and because of the uncertainty as to the probable initial head of the water found at any place, and because of errors in drilling and casing, it is difficult if not impossible with present records to determine the loss of head per mile of the water in a particular sand or connecting series of sands. In some places the more eastern wells show higher heads than do other wells to the west tapping the same formation at about the same horizon.

Ponded water.—Though the water that enters an artesian bed in the Coastal Plain deposits tends to move downward, that is seaward, toward some point of escape, ever getting deeper under cover, there are undoubtedly waters confined by sand beds pinching out or becoming clayey in all directions but one, and therefore practically stagnant. Such stagnant or ponded waters far below sea-level may be highly mineralized, because the sands in which they lie have not, since deposition in the sea ages ago, been thoroughly flushed by vigorous circulation, or because in depressions of the land the beds up the dip were saturated with sea water which displaced the fresh water below.

FLUCTUATION OF LEVEL IN ARTESIAN WELLS

Some agencies that cause fluctuations in the level of the upper surface of the ground water, the water table, cause fluctuations of the water in artesian wells. The most effective in Tidewater Virginia are changes of level in bodies of water on the surface. Since there can be no free communication between the deep and the surface water, otherwise the deep waters would not be artesian, there can be no direct transmission of water, nor of pressure, through porous beds. The pressure is transmitted through the relatively impervious beds that confine the artesian water. A river flood, a high tide, a flooded swamp means increased load; this pressure is transmitted downward to the covered sands through the saturated but impervious clays, causing a slight plastic deformation, and the water in wells sunk to the sands rises. In flowing wells this rise is shown by increased yield.

There are along Chesapeake Bay and its tributary rivers hundreds of wells showing marked tidal changes, some flowing only at and just after high water. In fact it is probable that all the deep wells on the shores of Chesapeake Bay or its tributaries show tidal changes, though in some the rise and fall of water are very slight and are not detected.

A change in atmospheric pressure can affect deep wells as it affects shallow ones. If the well flows, increased pressure may be shown by diminished yield. Near Sealston, in King George County, John Curtis has a 2-inch drilled well, 250 feet deep, that normally yields about two-thirds of a gallon per minute, the water rising only a few inches above the surface. This well flows most strongly before an easterly storm (when atmospheric pressure is less than normal) and during one period of cold weather with northwest winds (high atmospheric pressure) it ceased flowing for two days.

QUALITY OF ARTESIAN WATERS.

The wells drilled to the known Potomac sands are either near the western edge of the Coastal Plain or far to the east, there being none in the intermediate areas. Hence it is impossible to trace the changes in mineralization of the Potomac waters under cover. Similarly, as Upper Cretaceous beds have been recognized only in deep borings near Chesapeake Bay, nothing definite is known regarding the quality of the water in Upper Cretaceous beds further west. It is certain, however, that the waters in both the Potomac (Lower Cretaceous) and Upper Cretaceous beds show a progressive increase in mineralization toward the southeast, like the waters in the Pamunkey and Chesapeake sands. The increase in bicarbonates is the most noteworthy feature. Waters which near the outcrop of the beds may be either soft or hard, take up bicarbonates, and if originally hard become soft by losing much of the lime they contained. Such sodic bicarbonated waters are not peculiar to Virginia; they are found in other parts of the Coastal Plain, especially in South Carolina. But in Virginia they underlie the larger part of the Coastal Plain west of Chesapeake Bay, and are remarkable because they differ decidedly from the ground water from which they are derived, and because the change from the calcic bicarbonated (hard) ground water in the marl beds of the Chesapeake and Pamunkey groups to the sodic bicarbonated (soft) artesian waters, takes place during a relatively short underground journey. As a rule the artesian waters become more mineralized by taking up chlorine, bicarbonate, sulphate, and sodium radicles; that is, while there is a decided increase in the proportion of several acid radicles there is less increase in the basic radicles, except sodium.

At some places, as for instance, Hardings, Northumberland County, and Smithfield and Shoal Bay, Isle of Wight County, there are waters that are practically dilute solutions of sodium bicarbonate. Although chemists have reported high carbonate contents in the waters at several places, these waters may actually contain no carbonates, or little more than a trace. It is probable that at comparatively few places does the content of carbonates amount to over 30 parts per 1,000,000. The carbonate content reported in some analyses represents the chemist's opinion rather than the salts actually in solution.

Bicarbonated waters stimulate the growth of algæ. The difference in this respect between most ground waters and the soft artesian waters is striking. A heavy growth of "green moss" accumulates in troughs and about the mouths of flowing wells in many counties west of Chesapeake Bay.

Sodium bicarbonate waters have certain physiological effects and are not well adapted for all industrial purposes. Their healthfulness, their value in the treatment of disease, and their suitability for specific uses in the arts, are considered in another chapter.

ARTESIAN SANDS

Number.—It is extremely doubtful if there is a single water-bearing stratum in Tidewater Virginia that is of wide extent. The water beds are to be regarded as sands of varying porosity, laid down in interleaved lenticular deposits containing discontinuous streaks of hard rock. Thus while the wells along any given stretch of river may reach the same artesian zone, the depths to the points from which freest flows come may vary irregularly.

The total number of the artesian sands is unknown. Few wells have been sunk deep enough to prove all of them in the formations above the top of the Potomac group, and the Potomac, under cover the thickest of the groups, contains more sands than all the overlying formations combined. Yet except for what is told by the records of the Fort Monroe and Norfolk City Water Works wells nothing is known of the Potomac sands under cover far from their outcrops.

Potomac sands.—The Patuxent formation contains sands that under cover are probably as irregularly bedded as in their outcrops. Hence at one place the Patuxent may contain several beds freely yielding water, and at another not far distant show but one or two and these of feeble yield. Still, except in Norfolk, Princess Anne, Elizabeth City, and Mathews counties, and the eastern end of Gloucester County, good water is to be expected from the lower Potomac formation along the entire western shore of Chesapeake Bay, the mineralization increasing, deep under cover, toward the southeast corner of the State. The best chance for liberal yield is near bed rock rather than some distance above. On the Eastern Shore the Potomac lies so far below surface that there is little hope of getting good water from its lower beds. The most important wells drawing on the Patuxent are at Alexandria.

The Patapsco formation, or upper part of the Potomac group, contains water-bearing sands, though toward its outcrop only a few artesian wells are known to draw on them. Of the eastward extent of the Patapsco, as of the Patuxent sands, little is known. The upper part of the 1,300 feet or so of Potomac strata found in the Norfolk area has been shown to contain a number of water beds, and it is probable that under the whole of Tidewater Virginia, the upper Potomac contains artesian water, though the quality of the water is variable, and in the southeast part of the State is poor. On the Eastern Shore there is a possibility of getting fair water from the upper beds of the Potomac near the Virginia-Maryland line, but there is little chance of good water from the Patapsco formation in Northampton County.

For a fuller discussion of the quality of the supplies obtainable from the deep-lying Potomac beds the reader is referred to the account of the deep wells of the Norfolk-Newport News area in another chapter.

Pamunkey sands.—Though they vary irregularly in thickness, the water beds of the Pamunkey have much more continuous layers than those of the

Potomac, and because they lie nearer the surface have been drawn on by a far greater number of wells. They have been developed along the Potomac, Rappahannock, and James rivers, and reached by a few wells near Chesapeake Bay.

Of the two Pamunkey formations the Aquia is more important as an artesian reservoir than the Nanjemoy. The former underlies a wider area, and has been more developed along the Potomac and Rappahannock rivers.

The Nanjemoy formation is, however, an important water-bearer and near its base contains sandy beds that have been tapped by many wells between Potomac and James rivers. Little is known of the extent of the Nanjemoy formation south of the James; apparently it thins or is cut out along a northwest-southeast line so that few, if any, of the many wells in Southampton County draw on it.

Chesapeake sands.—In Tidewater Virginia the number of artesian wells drawing on Chesapeake sands is greater than the combined number of those drawing on Pamunkey or Potomac beds. This is because the artesian beds of the Chesapeake, in much the greater part of the area, yield fair to liberal supplies of good quality. Hence the beds below the Chesapeake have been explored only near or beyond the western edge of the Chesapeake outcrops, or where the Chesapeake supplies have been unsatisfactory.

Most of the artesian wells on the western shore of Chesapeake Bay in the territory lying east of a line running from Pope Creek, on the Potomac River, through Piping Tree, on the Pamunkey River, to Claremont, on the James River, draw on Chesapeake sands.

Well records along the Potomac and the Rappahannock rivers show a number of Chesapeake sands. They are thin and of varying persistency. The most persistent are in the lower half of the group in the Choptank (?) and Calvert formations, especially the latter. Those near the top, in the St. Mary's and Yorktown, are more patchy. Along York and James rivers the sands yield water less freely than to the north, and toward the mouths of these rivers the Chesapeake contains few sands that give flows and these are neither continuous nor regular.

On the Eastern Shore irregularly distributed sands near the top of the Chesapeake group, possibly high in the Yorktown formation, contain artesian water that supplies a few flowing wells along inlets from the bay or the ocean. This water varies in quality but on the average is very different from the artesian supplies found in Chesapeake beds on the western shore of the bay.

Columbia sands.—Generally thin, and for the most part lying above tide level, the Columbia sands on the western shore of Chesapeake Bay contain artesian water but rarely. Here and there "boiling" springs show artesian conditions but no flowing wells drawing on Columbia sands have been reported. On the Eastern Shore the Columbia sands are thicker and local conditions favor the storage of water under pressure in beds 50 feet or so below surface, which are here classed as Columbia.

The relation of some of the artesian water beds in the Potomac, Upper Cretaceous, Pamunkey, and Chesapeake groups are shown by the sections given in Fig. 6.

Flowing well areas.—As very few flowing wells in Tidewater Virginia have heads that are more than 35 feet above sea level, and heads on the Eastern Shore are under 10 feet, the flowing well areas are limited to the low ground bordering the bay or the ocean, and to strips of country of varying width along river and creek valleys. In other words, the flowing wells are confined to the shores, or to the terrace slopes. Enough drilling has been done to establish the extent of several artesian horizons west of Chesapeake Bay. It is certain that water which will rise above tide level can be had along the principal rivers from a short distance east of the "fall-line" to their mouths. Waters which will rise 25 feet above tide can be had along Potomac River east of Matthias Point, along the Rappahannock from 15 miles east of Fredericksburg, along the Mattaponi below Beverly Run, along the Pamunkey below Enfield, along York River, and along the James below Wilcox Wharf. Wells of high head can also be had around the east end of the peninsula between Potomac and Rappahannock rivers. Between Rappahannock and James rivers, however, in Mathews and Elizabeth City counties, several deep wells did not get flows and the yield of others has been disappointingly small. East of Norfolk, in Norfolk and Princess Anne counties, flows can be had, but the prospects for potable water from the formations which give fine flows to the west and northwest is distinctly unpromising.

Water that will rise 20 feet above tide, and in places even higher, can be had along Blackwater River south of McClelland, along Nottoway River south of Lumberton and along its principal tributary Assamoosick Swamp south of Littleton, along Three Creek east of Arringdale, and along Meherrin River from 15 miles below Emporia. As there are no topographic maps that show the lowest terrace along all the rivers, it is impossible to state the total extent of the area on the west side of Chesapeake Bay in which flows can be had.

Columbia sands.—Generally thin, and for the most part lying above tide level, the Columbia sands on the western shore of Chesapeake Bay contain artesian water but rarely. Here and there "boiling" springs show artesian conditions but no flowing wells drawing on Columbia sands have been reported. On the Eastern Shore the Columbia sands are thicker and local conditions favor the storage of water under pressure in beds 50 feet or so below surface, which are here classed as Columbia.

The relation of some of the artesian water beds in the Potomac, Upper Cretaceous, Pamunkey, and Chesapeake groups are shown by the sections given in Fig. 6.

Flowing well areas.—As very few flowing wells in Tidewater Virginia have heads that are more than 35 feet above sea level, and heads on the Eastern Shore are under 10 feet, the flowing well areas are limited to the low ground bordering the bay or the ocean, and to strips of country of varying width along river and creek valleys. In other words, the flowing wells are confined to the shores, or to the terrace slopes. Enough drilling has been done to establish the extent of several artesian horizons west of Chesapeake Bay. It is certain that water which will rise above tide level can be had along the principal rivers from a short distance east of the "fall-line" to their mouths. Waters which will rise 25 feet above tide can be had along Potomac River east of Matthias Point, along the Rappahannock from 15 miles east of Fredericksburg, along the Mattaponi below Beverly Run, along the Pamunkey below Enfield, along York River, and along the James below Wilcox Wharf. Wells of high head can also be had around the east end of the peninsula between Potomac and Rappahannock rivers. Between Rappahannock and James rivers, however, in Mathews and Elizabeth City counties, several deep wells did not get flows and the yield of others has been disappointingly small. East of Norfolk, in Norfolk and Princess Anne counties, flows can be had, but the prospects for potable water from the formations which give fine flows to the west and northwest is distinctly unpromising.

Water that will rise 20 feet above tide, and in places even higher, can be had along Blackwater River south of McClelland, along Nottoway River south of Lumberton and along its principal tributary Assamoosick Swamp south of Littleton, along Three Creek east of Arringdale, and along Meherrin River from 15 miles below Emporia. As there are no topographic maps that show the lowest terrace along all the rivers, it is impossible to state the total extent of the area on the west side of Chesapeake Bay in which flows can be had.

On the Eastern Shore, where the heads of the artesian waters are much lower, flows may be had along the shore in many places, as shown by the records in table 1. They can not be had at every place where the surface elevation is less than 5 feet, though it is probable that the flowing well areas will prove to be more extensive than the records indicate, particularly along the ocean side of the peninsula.

Some of the many flowing wells and the westward limits of flows from sands in the groups of formations are indicated in Plate I.

Conservation of artesian supplies.—The artesian supplies obtainable under the greater part of the region investigated are so abundant that their conservation and even their most advantageous development have received little attention. The situation at West Point and at Colonial Beach, where hundreds of wells no longer flow, depriving owners of advantages that in the aggregate have a large money value, shows that conservation can not be neglected. While such severe restrictions on the use of underground water as some states have imposed are not required, there is already need for local regulation. Waste is unnecessary and may work public injury. Where many wells have been driven those on low ground need not be allowed by unrestricted flow to diminish or cut off the flow of wells on higher ground. Neither is it right that the static head of the water in an underground reservoir should be lowered to the detriment of innocent parties by the insufficient casing of new wells or by the neglect of old wells. The casing of wells at wharves may be damaged by accident or corrosion, allowing a part or the whole of the flow to escape below tide level. It is obviously unjust to permit this where it means loss to other property owners, and where it can be prevented by the simple expedient of plugging the well. It is true that at both Colonial Beach and West Point there are undeveloped sands that can furnish plenty of water, and the depletion of all the sands is a remote contingency, but this does not alter the essential injustice of permitting the impairment of an important natural resource, and the depreciation of private property by carelessness and neglect, especially when preventive measures are simple and inexpensive. Sooner or later the fact that the interests of the public are superior to those of any individual will be so generally recognized that unnecessary waste will not be tolerated.

RECOVERY OF WATER

CISTERNS

The cistern is one of the oldest human devices for procuring a supply of drinking water, and it remains the most practicable source of supply in many localities. Cistern water is soft and is usually regarded as pure, hence cisterns are dug where ground waters are hard, irony or brackish, or are liable to pollution. In the Coastal Plain of Virginia there are some villages and many isolated dwellings that rely chiefly on cisterns. The sanitary quality of the water stored compares favorably with what is obtained by the ordinary type of dug well but is seldom as excellent as it is thought to be, since cisterns, like wells, may be polluted from below and from above. Some cisterns are not tight and impure ground water can find its way in when the level of the cistern water is below the water table. Many cisterns are not properly covered and back-yard dust and insects get in. The chief source of contamination, however, is from the roof. Dust, dead insects, and the droppings of birds fall on roofs and accumulate in eaves troughs to be washed into cisterns at the first shower. Where birds perch on buildings the danger of contamination is obvious, but even where such gross pollution is not apparent, danger may lurk. The small box filters of sand or charcoal, such as are often used, do little more than remove visible impurities; the bacteria that cause disease pass through. In fact, such filters, unless the contents are frequently renewed, may become breeding places for pathogenic germs.

Good cistern water is rain water properly collected and properly stored. Hence, cisterns should be tight, also they should be large, that only the best rainwater need be saved, that which falls at the end of showers when the air is free from dust and roofs and gutters are washed clean. There should be provision for diverting the water from the roof during the first part of a shower, and if filters are used they should be large so that the water will have to go through not less than 3 feet of fine sand before it reaches the storage chamber. In addition the cistern should be tightly covered and provided with a good pump. To allow farm laborers to bail water from a cistern is to invite infection.

SPRINGS AND SEEPS

Probably 90 per cent of all the springs in the Coastal Plain area issue as small flows from sandy beds in the Columbia formations, or from sands and marls in the Chesapeake. Some of the marl springs are of considerable volume although none are known that approach in size the large limestone springs of the western part of the State. In former days it was customary throughout Tidewater Virginia to supply the manor houses, when possible, with spring water—in fact the location of many houses was determined by the finding of a suitable spring. A wood or masonry basin and a wooden shelter as a spring house were the usual improvements, and buckets the means of conveyance, though sometimes a hand-power pump at the spring forced water to a tank in the house. It is no longer easy for the average household to obtain water in the old way, and the use of springs for household supply has greatly diminished.

Improvement of springs.—The improvements required at springs are few. A basin of tile or concrete, or even of wood, with a spout and a tight cover, are the chief requisites. The common arrangement of an open basin from which water is dipped, and steps leading down to the basin, facilitates pollution.

Use of rams.—To have a supply of spring water in a dwelling above the spring is in many cases neither difficult nor expensive. A ram costing perhaps $10 at point of shipment and a few hundred feet of pipe are the essentials. The yield obtainable is dependent on several factors—the fall from the spring to the ram, the height at which the water is to be delivered, and the distance of the ram from the spring and the point of delivery. A simple formula for rough calculations is one-seventh of the flow to four times the head—that is a ram fed by a flow of 7 gallons per minute under 7 feet head will elevate 1 gallon per minute to a height of 28 feet, or 2 gallons to a height of 14 feet. The smallest rams installed require at least 1½ gallons of water per minute for 3 feet of fall.

Objections are sometimes made to rams and tanks. The commonest is that by storage the water becomes unpalatable. Against this is the convenience of tap water. Between a well-situated spring and a dug well situated and curbed as too many are, the sanitary advantages are all with the spring. The main point in installing a ram is to have ram and pipe large enough to handle the water easily. Failure to measure the quantity of water available and the use of too small equipment are the chief causes of disappointment with new installations.

COLLECTING TUNNELS AND DRAINS

General statement.—The point where the upper surface of the ground water, or where some water-bearing sand reaches the face of a bluff or terrace scarp, is frequently more or less hidden by wash. Hence it has happened that a small visible flow has been utilized when a larger yield could have been had by a little digging in a better situated or more convenient place not far distant. Where seeps on the faces of bluffs cause landslides that may destroy the beauty of a dwelling site, or do other damage, a small outlay of labor may not only stop the danger but develop a liberal supply of water less liable to contamination than that obtained by dug wells on top of the bluff.

Mount Vernon collecting tunnels.—A good example of how to make the most of such springs is to be seen on the face of the 125-foot bluff at Mount Vernon, on the Potomac. Here small flows and seeps of water that emerge at 50 feet above tide from Potomac sands locally indurated to ferruginous sandstone, caused slips of overlying clay beds which threatened serious injury to the premises. The bluff shows the following section:

Section of the bluff at Mount Vernon on the Potomac.

Group and formation	Material	Thickness	Depth
COLUMBIA, Sunderland	Soil	1	1
	Gravel	7	8
POTOMAC	Dry red clay	20	38
	Brown and yellow clay	25	63
	Putty clay, pockets of water	2	65
	Sand and sandstone indurated by iron near face of the hill where tree roots reached water; water-bearing at base	10	75
	Dry blue clay	7	82
	Dry red clay	20	102
	Brown and yellow clay	10	112
	Dry putty clay	1	113
	Dry sandstone, no water at contact with clay below	4	117
	Blue clay	6	123

Under the direction of William Archer tunnels 6 feet high and 3½ feet wide were run nearly east and west in the 7-foot bed of blue clay below the sand and indurated sandstone. The first tunnel, which carried 2 feet of blue clay in the headings, was driven east 279 feet on a grade of 2 inches in 100 feet, and cut all seeps on clay level at right angles. At a sudden V-shaped depression, which carried much water, an underdrain 4½ feet deep and 2½ feet wide was dug. In this ditch 2-inch tiles were laid on 3 feet of rammed gravel, and covered with coarse washed gravel. Another tunnel was driven west 121 feet and filled with gravel. In August, 1906, the long tunnel was flowing 10,500 gallons in 24 hours, and the short tunnel 7,500 gallons.

The flows from the tunnels go to brick catch-basins, thence to two rams situated 18 feet below. With both rams running, 2,500 gallons a day are pumped to tanks 150 feet above river level.

According to Mr. Archer, the tunnels have dried the face of the bluff for twice their length, have stopped land slips, and are an unqualified success. They seem to drain the overlying Columbia gravels as well as the spring bed. A 20-foot dug well on the terrace, 80 feet above the ditch, is said to have gone dry since the completion of the tunnels, and the water in another dug well 100 feet from the bluff has been preceptibly lowered.

In ordinary practice there is no need of tunneling to develop hill-side springs. A gravel-filled trench to the bottom of the water-bearing bed, a covered catch-basin, a ram and pipe are enough. Since the work can be done when other farm duties are not pressing the labor expense may be small. There are many seeps and wet spots along the higher terrace scarps and river bluffs in Tidewater Virginia that can be developed by a little trenching.

WELLS

With the lessened use of springs as sources of domestic water supply there has been a great increase in the number of wells, until now, in most rural communities, every house has its well. As the wells are sunk to recover underground waters that are found under very different conditions, they vary greatly in depth, diameter, and yield, but may be divided into four classes as follows: (1) Dug wells; (2) Bored wells; (3) Driven wells; (4) Drilled wells.

Dug wells.—At present, chiefly because of its low first cost, the dug well is the mainstay of a majority of the inhabitants of the Virginia Coastal Plain. Except in a few counties, or in exceptional locations, enough good water for the needs of an ordinary household can be had by a dug well close to the house and less than 50 feet deep, and the labor cost of such a well, dug at a time when other farm work is not urgent, is more or less nominal. In most parts of the tidewater country the only laborer specially employed is the digger, and he may ask but $5.00 for digging 35 feet.

Wells dug for household supply are 3 to 6 feet in diameter. When sunk through firm loam and sandy clays that will stand without support, usually no lining is placed, except enough at the bottom to keep the sand in the water-bed in place. This lining is of 2-inch plank, 12 to 16 feet long. Where water lies near the surface the wells are often lined with plank or boards from top to bottom, and have circular, octagonal, or square cross-sections. In some localities the sandy soils will not stand and wells must be lined throughout, even though water lies 40 feet below the surface.

The total cost, labor and materials included, for many a 35-foot well, wood casing, curb, rope, and bucket, has been under $20.00. Wells cased with brick or tile cost more—the prices asked by well diggers for digging a well and placing brick, running from 50 cents to $1.00 per foot of depth.

The usual method of lifting water from the dug wells is by bucket with rope or chain, and windlass or pulley. At a few wells sweeps are still used. At an increasing number of wells are wooden lift-pumps or iron force-pumps, but the bucket is found in at least four-fifths of the country wells.

The great majority of the pumps are operated by hand-power. In some localities windmills are used, and here and there are gasoline engines.

Open wells of the sort most often seen rank among the most effective spreaders of disease. Wayfarers and transient laborers handle the bucket with their dirty hands, small animals fall in, and all manner of impurities, such as the droppings of fowls that have had access to privies, or filth from the feet of laborers who have been working about manure heaps, are washed in at every heavy shower. If a bed that is water-bearing in wet weather is met part way down the walls of the well heave at that point, the casing deteriorates rapidly, and in a few years a break comes, with a rush of sand. Repairs are troublesome and may be more expensive than digging a new well. In such a case the old well is often filled carelessly, adding to the unsanitary surroundings of the new one.

A well should be considered a permanent investment, and if not lined throughout with tile or cement should have a water-tight lining for several feet from the top. The top should be covered with a good sloping platform, and a pump that does not need frequent priming should be put in, to avoid the contamination of the well water by any water used for priming.

Bored wells.—This term is here applied to wells dug with an earth auger. Such wells are usually from 8 to 12 inches in diameter, and can be sunk cheaply where soils are free from large boulders. Most are covered, have pumps, and are, if curbed with tile, superior to wood-curbed dug wells. They are of course cheaper than dug wells curbed with large tile but their reserve capacity is smaller. While not so good for obtaining supplies from beds that transmit water slowly, bored wells are much less liable to serious pollution than dug wells.

Driven wells.—Driven wells consist essentially of an iron pipe with a pointed cap, are usually 1½ or 2 inches in diameter, and are driven to a water bed. They are particularly adapted to localities where soils are easily penetrated and water lies in loose, coarse, clean sands. Wells 10 feet deep or less may be driven by a maul. Wells over 20 feet deep are usually driven by a hammer worked by a block and fall. The extreme depth to which a pipe can be driven depends on the character of the soil, but may exceed 100 feet. If the subsoil clay is tough, an earth auger is used to make a hole for the pipe. The water enters the well through holes in the cap and near the bottom of the pipe. To keep out sand galvanized iron screens are sometimes used, and, if the sand is fine, screens of brass gauze as fine as 60 mesh may be needed.

Driven wells may be equipped with cheap pitcher pumps, costing $2 to $5, wood pumps, or force pumps, the latter worked by hand or by a windmill. The obtainable yield varies with the transmission rate of the water bed, depth to water, size of pipe, and the pump.

From a sanitary standpoint, a driven well is much superior to a dug or bored well. If the pipe is driven 10 feet or more below the lowest level of the water table, has a collar of concrete to hold it firmly and prevent surface water from working down along it, and is topped by a good pump, that does not need priming, a driven well is safe from surface pollution.

There are hundreds of driven wells 1½ or 2 inches in diameter and 5 to 50 feet deep in the low terraces of the Virginia Coastal Plain. They are very numerous in Norfolk, Princess Anne, Accomac, and Northampton counties. With an ordinary pitcher pump the average yield is about 3 gallons per minute. The total cost of a driven well varies with the depth and the equipment. For wells 5 to 50 feet deep the cost ranges from $3 to $40.

Drilled wells.—Under this head are included all wells sunk by drilling rigs, whether of jet, rotary or percussion types. Diameters range from 1 to 15 inches; depths from 50 to over 2,000 feet.

In the tidewater counties the deeper wells—most of those over 50 feet and very nearly all over 100 feet deep—have been sunk by rigs of the jet type. In these a stream of water is forced down a hollow drill rod and washes up the material loosened by the reciprocating bit. If the beds penetrated are loose, casing must be placed as the boring advances. In firm, compact sandy clays the hole will stand without casing. If no hard layers or loose sands are encountered progress is rapid, and by hand power alone a depth of 400 feet can be reached.

Hand power rigs have light derricks made of wood or of iron pipe, and are worked by two or more men pulling on a rope leading over a head pulley, the bit being rotated with a wrench. Two other men are needed to work a pump to force water down the rod through openings in the bit and up the casing, and wash out the drillings. In firm sands free from hard "rocks" a hand power jet rig put down a 1½ inch hole 150 feet in half a day, but should one or more "rocks" be encountered, even though these be but a foot or so thick, a driller may be a week or two in completing a well.

Drillers have sometimes substituted horse for man power, but practically all wells over 300 feet are now sunk by rigs with gasoline or steam engines. With these rigs, wells 2 or 3 inches in diameter have been sunk over 1,000 feet through the Coastal Plain beds. Various types of gear are used for giving a reciprocating motion to the drill rod. A rig capable of sinking a 3-inch hole 1,000 feet requires the services of a driller and a helper. The rate of progress, hence the total cost of drilling, depends largely on the skill and resourcefulness of the driller. Hard beds give trouble, but rapid progress is made through firm sands.

For wells of large diameter, such as are needed for city supply or for the equipment of manufacturing plants, three types of drilling outfits have been used in the Virginia Coastal Plain; the jet, the rotary hydraulic, and the standard cable, all of which require for heavy work a driller, a helper, and one or two laborers.

The rotary hydraulic rig has a revolving bit down which water is forced. It is particularly suited for rapid advance through soft or unconsolidated deposits. The chief objection to its use in a district where the water-bearing beds are thin and have not been definitely located, is that a sludge of mud and water is used to plaster the sides of the hole to prevent sand beds from running. By keeping pressure on a pump and forcing down mud a driller need not place casing and can therefore make rapid progress; this tempts him to neglect possible water beds, particularly if he is working at so much per foot. One well in Tidewater Virginia, said to have been sunk by this process 1,000 feet without casing, was not a success, though flows were found at lesser depths by other wells in its vicinity.

The standard cable rig, the best type, all things considered, for going through rock, is not particularly adapted for work in the Coastal Plain sands and clays. In most localities the casing has to follow the bit closely, and even a careful driller may have great difficulty in getting through loose sands which sometimes rise in the casing 100 feet over night. Sudden inrushes of sand may bury the drill, causing vexatious delays. Again the frictional resistance of the sands may prevent the casing, after several hundred feet are placed, from going down by its own weight; then it has to be driven and heavy driving may break it at some joint, causing its collapse and the loss of the well. All things considered the jet rig is perhaps the best of the types in use, though in places what is known as the California stove-pipe rig could be used to better advantage.

The actual cost of drilling a given well and the price asked by the driller may differ greatly. The driller assumes the risk of accidents and unforeseen delays, can not work all the year, and has to bear the expense of moving and setting up his rig. The drilling cost varies with depth, the rate of advance, the casing needed, etc. Where drilling is good the actual labor and power cost of a 1½-inch well 150 feet deep may be $10; if hard "rocks" are struck the cost may be $75. The cost of larger wells varies as widely. Under favorable conditions a six-inch hole can be sunk 1,000 feet for $1 per foot, excluding casing, but more than one driller has lost money contracting to sink 500 feet for $2 per foot.

The usual price for a cased six or eight inch well from 200 to 500 feet deep has been $3 per foot.

Most of the small diameter wells are sunk on a "flow or no pay" contract. Where a driller knows that at a certain depth water can be struck having sufficient head to rise above the well mouth he will contract at a low figure, whereas in territory that is new to him, or where the surface elevation makes a flow doubtful, he will ask much more. Large diameter wells are usually sunk at so much per foot, the price increasing below certain depths, or under a contract to get a flow and complete the well for a certain price. Whether the owner is liable to lose more at the hands of an unscrupulous driller by contracting for a flow at an unnecessarily high price than by having the driller working at so much per foot, pass by water beds to run up the total cost, is a question. The fairest contract, where conditions are unknown, is one which protects the driller from loss and stimulates him to do his best. Such a contract should be at a certain price per foot, with a bonus for obtaining the desired flow within a given time, or above a given depth.

Speaking generally, the cost of a well may run from 10 cents to $5.00 a foot, depending on the diameter of the well, the length of casing needed, and the material penetrated. The writer knows of a fine 1½-inch well 150 feet deep, that cost, casing and all, but $18, and of a 6-inch well 1,000 feet deep that cost $4,000.

The most expensive well ever drilled in Tidewater Virginia is the one sunk at Fortress Monroe in 1902. This had 15-inch casing to 720 feet, 12-inch casing to 1,200 feet, and 9-inch casing to 2,128 feet. From 2,128 to 2,250 feet no casing was placed. The contract price was $34,820.

MAGNETIC WELLS.

The only magnetized well in the tidewater region to come to the writer's notice is that of J. M. Shackelford at Severn, in Gloucester County. At first the casing is said to have had magnetism enough to hold up a 10-penny nail, but in November, 1906, two years after the well was drilled, the magnetism was just sufficient to draw from the perpendicular a small iron key suspended from a ring.

The reason for the magnetic action of the casing is simple. The earth is itself a great magnet; the drill falling at right angles to what are known as the lines of force becomes magnetic, the jar of the bit helping the particles of steel in it to become polarized. By the scraping of the bit on the casing the latter is magnetized in much the same way as a knife blade is by rubbing it on a pocket magnet. The duration of the magnetic effect depends on the physical structure of the metal in the casing and on the original intensity of magnetization.

Claims that magnetic waters flow from such magnetized wells have been made, but have not been verified. The casing of the well at Severn is said to have shown a stronger effect when the water was running than when the flow was shut off. That such was actually the case seems doubtful.

YIELD OF WELLS

When the water in an open well is lowered by bailing or pumping the upper surface of the ground water is locally depressed, and under continued pumping falls until the increased rate at which the water enters the well from the surrounding sands by reason of the pressure toward it, equals the rate of bailing or pumping. The rate at which water flows to the well depends on the difference in pressure between the water at the instant it enters the well and the water in the surrounding sands, as measured by the local depression of the water table, and the ease with which the sands transmit water. As has been stated, every soil has a certain porosity determined by the size of the voids between the soil particles, and every soil has, at a given temperature and a given difference of pressure, a certain rate at which it will transmit water, called its transmission constant. The conditions governing flow to wells have been studied by Schlichter, among others, who says:

"The amount of water yielded by a common well or by a non-flowing tubular well is dependent first of all upon the degree of fineness of the material in the various strata from which the water is obtained. The size of the soil grains not only determines the rate at which water can be transmitted to the wells under a given head but it also determines the proportion of contained water the soil will freely part with. The fine-grained soils retain a considerable proportion of the water of saturation as capillary water even after free means of drainage are established, so that fine-grained materials will not only deliver water slowly but will furnish only a small total amount. Some quicksand is so fine that the waters can be pulled away from the fine grains only with the greatest difficulty."[a]

The same general principles apply to artesian and flowing wells as to shallow open wells. The yield of water depends on the difference in pressure between the water in the well and the water in the sand, on the temperature (which for deep wells is unvarying), on the porosity, or rather the transmission constant of the sand, and on the thickness of the sand. These factors account for all the differences observed in the yield of flowing wells, except such as are due to faults in drilling or maintenance. Fine sands, imperfectly assorted sands, and clayey sands transmit water less freely than coarse, clean, evenly assorted sands, and coarse gravels transmit water still better. The boldest flows in the tidewater country come from beds of coarse, rounded sand or from beds of smooth gravel.

LOSSES OF HEAD OR YIELD IN FLOWING WELLS

Causes.—The commonest complaints of a well owner are that the water in his well will not rise as high as when the well was just completed, or that the yield is less, and that if he wants as much water as he had at first he must have a new well sunk. The causes of lower head and lessened yield are various, and the responsibility may rest on one or on many persons. The causes may be summarized thus:

(1) Faults in sinking; such as (*a*) improper casing, (*b*) lack of screens.

(2) Faults in maintenance; such as (*a*) neglect, (*b*) abuse.

(3) Interference.

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[a] Schlichter, C. S., Field measurements of the flow of underground water, U. S. Geol. Survey, Bull. No. 140, p. 87.

FAULTS IN SINKING.

The desire of a driller to economize on casing has resulted in reducing the flow of many a well. Where the clayey Chesapeake or Pamunkey sands above the water bed would stand without casing it was customary for a driller to place casing through the overlying Columbia or Recent material and bottom it in the sandy clay, possibly using in all only a length, about 20 feet. Such work permitted (1) the sub-surface escape of water, by leakage, about the bottom of the casing, or the escape of water below the casing from a deep sand into a higher one; (2) the clogging of the well by material washed from the sides but too heavy to be carried up and discharged by the flow.

Some drillers instead of placing casing to the water-bed carry it down to an impervious layer, but leave a small pipe, usually the ¾-inch drill rod, in the well. This diminishes the danger of the well clogging but does not prevent possible leakage outside the pipe, which only half fills the hole of water from the deep sand into a sand nearer surface.

Screens have been little used in small flowing wells on the western shore of the bay. Their use might diminish the possible yield, but would maintain the flow, of many wells sunk into loose sands and showing low initial heads. On the Eastern Shore screens are used at many wells because the loose sands and soft clays soon clog unscreened wells, or because at pumped wells the sands damage pump valves and cylinders.

FAULTS IN MAINTENANCE.

Neglect.—Most flowing wells, like non-flowing driven or dug wells, receive too little care from owners. Many flowing wells, particularly those of low head tapping loose sands, need to be cleaned occasionally. The sand can be washed out with a good force pump and enough pipe to reach the bottom of the well. A well with a screen is sometimes clogged by sand grains packing against the screen. In such a case the flow may be restored by forcing water down the casing, thus loosening the packed sand.

Abuse.—Under the head of abuse come dropping in pebbles or other objects too heavy for the water to lift, attempts at cleaning with a sash weight and string (a plugged well may be the result) and momentarily stopping the flow by the hand or otherwise. A momentary stoppage of flow may have no effect on some wells, particularly properly cased wells with high head, but at others it may permit loose sand in the casing or the bore hole to pack, thus greatly reducing if not cutting off the flow. Any sudden interruption of flow in a well not cased to the bottom may loosen material above the water sand and clog the well.

Generally speaking, it is not advisable to shut off a flowing well, but where unrestricted flow may affect the head of nearby wells the flow may be reduced to a small fraction of the normal volume. The reason for not shutting off the flow entirely is that more than one well has had its flow reduced or cut off by children or older persons closing the pipe with their hands.

INTERFERENCE.

The total supply of water in the artesian sands of the Virginia Coastal Plain is practically inexhaustible, but it is easily possible to draw so much water from a particular part of a bed, especially if the bed be thin, that the head of the water in that part of the bed is decidedly reduced. Such reduction of flow has happened at various places along the Rappahannock River; also, and especially, at Colonial Beach and West Point.

At Colonial Beach the first artesian wells found water, at a depth of about 200 feet, that rose fully 20 feet above tide level, or above the surface at the highest points in town. Possibly 200 wells have been drilled in an area 1½ miles long and half a mile wide. No restrictions have been put on flow and a few of the wells are pumped heavily. As a result the head of the water in the 200-foot sand has been so reduced that most wells in the center of the town do not flow at the surface, and many at lower elevations flow only at high tide. Many wells back from the water front have been cut off below the surface and now flow into basins 5 feet or so deep. The lowest wells, those along the shore, drain those on higher ground. The sinking of one well on the water front has stopped the flow of a neighboring well on ground a few feet higher. Many of the wells were poorly cased and there is probably much leakage underground. That this loss of head is purely local is shown by the high heads of wells tapping essentially the same horizon at points a mile or two from town.

At West Point where over 300 wells have been driven the loss of head has been even greater than at Colonial Beach, but conditions are more complicated. The city is on a point of land at the junction of the Mattaponi and Pamunkey rivers. There is a water-bearing sand at 120 feet and another at about 165 feet. Along the water front many wells have been drilled and allowed to flow without restraint. As a result wells on higher ground that formerly flowed now have to be pumped. The 120-foot sand that once furnished flows is now penetrated by many poorly cased wells sunk to the 165-foot sand, and the water flows down these holes to the 165-foot sand and escapes from the river-front wells tapping the latter sand. The maximum local loss of head in the 165-foot wells has been about 15 feet; in the 120-foot sand even more. According to E. W. Wilkinson, a well sunk in 1884, and one of the first if not the first in the town, flowed at an elevation of 14 feet above surface, or 20 feet above tide. After about a year and a half, when a number of wells had been drilled, the flow decreased and now the well is pumped. Isolated wells above the city or across the rivers show undiminished heads.

The manner in which poorly cased wells and wells near river level have reduced the head of the water in the 120-foot and 165-foot sands at West Point is indicated in Fig. 7.

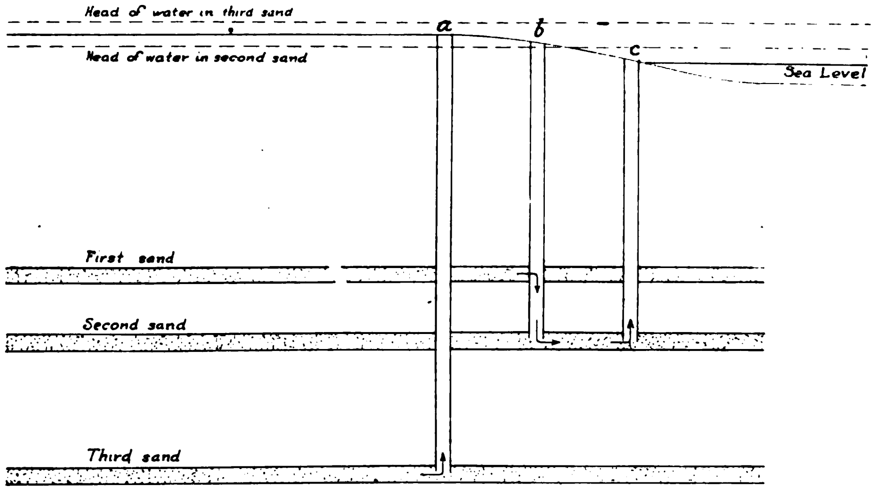

Fig. 7.—Diagram illustrating artesian well relations at West Point. *a*, properly cased well which obtains a flow from the third sand; *b*, improperly cased well on high ground, no flow; *c*, well at river edge; flows continually, draining third sand, also second sand through well *b*.

From an examination of several hundred flowing wells in the Coastal Plain of Virginia the writer ranks the causes of decline in yield as follows: (1) interference; (2) neglect; (3) improper casing; (4) abuse.

Utilization of Supply.

The great majority of the flowing wells in Tidewater Virginia are of small diameter, 2 inches or less, and yield about 2 gallons a minute at the well mouth. This yield with proper economy is liberal for an average household. In great manufacturing cities where the installation of meters on all service mains has reduced the consumption of water to actual requirements the daily consumption is as low as 50 gallons per capita. The average person drinks about 3 pints of liquids per day and 25 gallons per capita has been estimated as sufficient for all domestic needs. Hence a flow of 2 gallons per minute, or 2,880 gallons per day, if storage capacity is provided, will not only more than suffice for a household of average size, but the overflow piped to the barn will water many head of stock, allowing 8 gallons per head.

Yet at most places in Tidewater Virginia there is little effort toward economy. On the other hand, there are a few places, notably Tappahannock, where the superiority of the deep waters to those obtainable from dug wells is so much appreciated that wood or concrete tanks are built at some well mouths from which the water is piped to pumps or taps at two or three houses.

Rams at flowing wells.—Where a house and farm buildings stand on a terrace 25 feet or more above river or bay level and flows on the terrace are impossible, an abundant supply may be had for dwelling and barn by harnessing a hydraulic ram to a flowing well of good head below the terrace and piping the water to a tank. A flow of 5 gallons per minute at 10 feet above tide level can be had along many inlets on the lower courses of the rivers on the west side of Chesapeake bay. If properly placed and connected, to utilize 7 feet of this head, a ram costing possibly $15 will afford 1 gallon per minute at 40 feet above the ram. There is little difficulty in thus making a flowing well pump its own water. The most essential feature of the equipment is a basin, small tank, or stand-pipe between the well and the ram; the ram should never be connected directly to the well. There are in Tidewater Virginia a number of wells with rams that give satisfactory service. Some failures reported were due to not determining in advance the available head and flow and the amount that could be delivered at the desired point; other failures were due to improperly placed or connected equipment.

SANITARY PROTECTION OF WELLS

In drilled wells there is ordinarily slight danger of pollution except from the top, because the tight iron casing protects against sub-surface contamination. Yet one can see wells that cost $200 sunk to sands that yield beautiful water, into which all kinds of backyard refuse are washed at every rain, simply because the top of the casing or the pump chamber is not properly protected, a defect remedied at trifling expense. Flowing wells, such as those in the Virginia Coastal Plain, are practically unpollutable, and it is to this fact that the improved health of particular communities after the development of artesian supplies has largely been due.

The greater the number of people that may use a well the more urgent the need of the well water being free from disease germs. Also it is evident that if many people use an open well there is more chance of some person who carries disease germs handling the bucket and thus contaminating the well water. Consequently, wells at churches, camp-meeting grounds, courthouses, and schoolhouses need to be dug and protected with more than ordinary care. Many cases of typhoid fever have been traced to such public or semi-public wells, and yet the precautions taken against the pollution of well water at many gathering places in the tidewater country are practically of no account. Usually the most that is done before a camp meeting is to clean the dug well. This is a wise precaution but does not lessen the chance of the water being polluted during the meeting. Absolute safety means making pollution impossible. This implies location with regard to natural conditions of drainage—most church and courthouse wells in the tidewater country satisfy this requirement—and then, if water can not be had by a driven well and a deep drilled well would be too costly, providing a water-tight casing extending several inches above and at least 5 feet below ground level, a water-tight cover and a good pump. The open well and the oaken bucket may appeal to sentiment but the tightly cased well and the force pump are far more sanitary.

Even though a drilled or driven well is properly sunk and has a good pump, occasional inspection is necessary to make sure of an unpolluted supply. A virulent outbreak of typhoid at one locality in the tidewater country was traced to the schoolhouse well. This well had been sunk to an artesian sand, the water from which rose to within a few feet of surface. As the artesian water was known to be excellent the well was not suspected until the coming of the fever, which attacked 40 per cent of those who drank the well water. Investigation showed that the casing had rusted through at ground water level, a few feet below surface, and in consequence the well for an unknown length of time had not drawn on the artesian supplies but on a polluted source.

PUBLIC HEALTH AS RELATED TO UNDERGROUND WATER SUPPLY.

Without accurately kept mortality tables covering a term of years, it is practically impossible to prove or disprove statements regarding changes in the death rate or in the prevalence of particular diseases at specified communities. Hence, statements regarding the effects of changes in the conditions of living in the smaller settlements and the rural districts of the Virginia Coastal Plain are of value only in so far as they are put forth by persons who are familiar with the conditions and are competent to judge. For this reason the testimony of local physicians is of decided value. In their opinion changes in sources of water supply in towns, villages, and on farms have been followed by definite changes in the prevalence of specific diseases, more especially typhoid fever and malaria. Following the lessening use of springs as sources of supply and the increasing use of unprotected dug wells, there was a marked increase in typhoid. The substitution of driven and drilled wells for open wells at particular villages has notably diminished the prevalence of this disease and lowered the death rate. In addition physicians living in widely separated communities claim that the development of artesian supplies in the lowlands along the rivers has practically freed many tracts from the malarial fevers for which they were once notorious.

MUNICIPAL WATER SUPPLIES

SOURCE OF SUPPLY

Some of the towns and cities in the area covered by this report have waterworks that distribute surface water, a few have plants that draw on underground supplies. The surface water is variously obtained from rivers or ponds, the underground water from shallow or deep sources.

SURFACE WATER

Rivers and creeks are the more important sources of surface water. They are subject to great variations in volume of flow and quality of supply; at times of flood they contain much finely divided mineral matter in suspension or semi-solution, and are extremely turbid. Many of the surface waters are polluted; the large rivers by the sewage of cities, the creeks by drainage from privies, barnyards or cultivated fields. The ponds drawn on are as a rule less liable to pollution, but vegetable growths frequently make the water high-colored or give it an offensive smell and taste. In consequence, most of the public supply systems include equipment for rendering the water more acceptable, ranging from simple settling basins to elaborate filtration plants.

UNDERGROUND WATER

Though the porous sands of the various Coastal Plain formations form great underground reservoirs, they are much less important as sources of municipal water supply than rivers and creeks. This is because there are few cities or towns of large size along the middle portion of the Virginia Coastal Plain where the underground waters, and more especially the artesian waters, are most readily available. The cities are chiefly on the western edge of the Coastal Plain, where flowing wells can not be had and the ground water supplies are not sufficient for the needs of large cities; or towards the seaward edge where the deep artesian water is not well suited for municipal use, and satisfactory shallow water is restricted to certain areas.

SUITABILITY OF SURFACE AND UNDERGROUND WATERS FOR MUNICIPAL NEEDS.

The belief that underground water is better, that is more healthful, than surface water is widely held, but rests on the sparkle, clearness, coolness and taste of well and spring waters rather than on careful investigations of their merits.

Surface waters are often badly polluted but settling and filtration render them innocuous; the water furnished by the supply systems of the larger cities in eastern Virginia is, from a sanitary standpoint, altogether superior to that obtained from many dug wells in villages. The deep artesian waters are unpolluted, but under a considerable part of the Virginia Coastal Plain they contain enough mineral salts to make them less suitable for boiler supply and other industrial purposes than filtered surface water. The latter, as a rule, contains little lime and the addition of the chemicals for precipitating finely divided matter does not increase the mineral content enough to affect the industrial value of the water as distributed. In general it may be said that nearly all of the public supply systems distribute good water, that is, water which satisfies sanitary and industrial requirements. In fact, most of the cities of Tidewater Virginia have reason to be proud of the excellence of their public water supplies.

NOTES ON CITY AND TOWN SUPPLIES

The city of Richmond owns its water supply system. James River receives the sewage of several cities and towns and is often very turbid.

The water is collected in a settling reservoir above the city limits and after purification is pumped to the mains and to smaller distributing reservoirs on high points in the city. Careful determinations of the variations in turbidity, and chemical and bacterial quality of the water were made during a number of years, and on the basis of the results the city installed a sedimentation and coagulation plant. The water after treatment is remarkably clear. The municipal waterworks in Manchester distribute James River water, collected above the city at a point opposite the intake of the Richmond city waterworks and purified by sedimentation and mechanical filtration.

Barton Heights, a suburb of Richmond, was supplied in 1910 with water obtained from a spring and from a well 759 feet deep.

Norfolk gets water from three distributing systems. The city waterworks, which supply most of the city, draw on small lakes in low ground northeast of the city; the sanitary surroundings of these in 1906 were good. Complaints of color and odor, caused by vegetable growths, led to the installation of a coagulation and filtration plant, and the water supplied is now satisfactory. To meet the prospective needs of the city other sources of supply have been sought. Part of Norfolk and several suburban towns, Lambert's Point, Ocean View, Huntersville and Lindenwood, are supplied by the Norfolk County waterworks, which get most of their supply from a system of driven and dug wells on a tract of land near the lakes that supply the city works. This ground water is of good quality and is distributed by a direct pressure system without filtering. To supply an increasing demand the company has investigated the development of surface waters similar to those distributed by the Norfolk City waterworks. The eighth ward of Norfolk, formerly the city of Berkeley, is supplied by the Norfolk, Berkeley & Suffolk Water Co. Most of the water comes from a system of shallow driven wells on a tract of land not far from Berkeley, but part comes from Smith's Creek (Lake Kilby) near Suffolk. The well water is of satisfactory quality but the quantity obtainable on the tract near Berkeley is insufficient for the prospective needs of the community.

The cities of Suffolk and Portsmouth are supplied by the Portsmouth, Berkeley & Suffolk Water Co., with Lake Kilby water. The water of Lake Kilby is high-colored and at times has an objectionable smell. The water distributed passes through a coagulation and sand-filtration plant which reduces the color and removes the odor.

The city of Newport News, the city of Phœbus, the town of Hampton, the Hampton Agricultural and Collegiate Institute, the National Soldiers'

Home, near Hampton, and the military post of Fort Monroe, are supplied with water by the Old Dominion Water & Power Co. This company has a large reservoir in Warwick County, controls practically all the watershed (about 1,500 acres) of the creeks feeding this reservoir, and endeavors to protect the watershed from pollution. Because of complaints of high color and disagreeable odor the company installed a coagulation and filtration plant (mechanical filters) and the water is now satisfactory.

The city waterworks of Petersburg distribute surface water obtained from Livetenant Run, a creek that empties into Appomattox River on the east side of the city. The watershed of the creek is open to pollution from dwellings, but the creek water is passed through a settling and coagulation basin and is filtered before distribution, consequently its quality is satisfactory.

Fredericksburg owns its distributing system, which obtains water from a canal of the Rappahannock Power Co., supplied by a dam on Rappahannock River three miles west of the city. The river is often very turbid and local conditions do not tend to improve the quality of the water passing through the canal, but a collecting reservoir at the pumping station permits decided improvement by sedimentation. From the collecting reservoir the water is pumped to a distributing reservoir on the heights south of the city. A considerable number of people in the city obtain water from the mains of the Aqueduct Company. This water comes from several springs, none of large size, on the high ground south of the city, and is generally of satisfactory quality.

Alexandria has city waterworks that distribute water from Cameron's Run, a creek on the south side of the city. The water is collected three miles west of the city and brought by a canal to a pumping station, whence it is forced to settling and distributing reservoirs on Grimes' Hill. The run water is often turbid, the water shed is inhabited, and conditions along the canal are not altogether satisfactory. However, the quality of the water is decidedly improved by sedimentation in the settling reservoir.

The city waterworks of West Point draw on artesian wells that tap sands 330 feet below surface. The sanitary excellence of this supply is not disputed, but its industrial value would be greater were the water less mineralized; it contains considerable bicarbonate and sulphate of soda and in boilers has a tendency to foam.

The town of Franklin has a public supply system drawing on Blackwater River. The water is pumped from the river to a tank on a high tower; it is a good boiler water but at times is objectionable for drinking.

The Smithfield supply is from a pond on a small creek three miles west of the town. It is not filtered, but the small watershed of the creek is sparsely settled, and except for vegetable growths the quality is satisfactory.

The town of Emporia distributes Meherrin River water. An attempt to get water by a deep well gave unsatisfactory results.

Practically all the water distributed by the municipally owned system of the town of Cape Charles comes from driven wells varying in depth from 30 to 90 feet. The supply is not altogether satisfactory, partly because the wells are close to tidewater. The water is hard and forms scale in boilers.

The Onancock waterworks draw on driven and drilled wells less than 75 feet deep, and on a large dug well. The water, while slightly hard, works well in boilers, and except for the possibility of polluted water entering the dug well, the sanitary surroundings in 1906 were good.

The military post of Fort Myer, west of Alexandria, is supplied with filtered Potomac River water. Fort Hunt on Potomac River, below Alexandria, obtains excellent water from an artesian well.

A summarized statement of information collected regarding the public water supply systems of the Coastal Plain towns and cities appears in table 2.

TABLE 2.—*Municipal water supplies in the Coastal Plain Province of Virginia.*

City	Owner	Source	From what distributed	Capacity of reservoir (*gal.*)	Elevation of reservoir or standpipe above town (*feet*)	How distributed
Alexandria	City	Cameron Run	Reservoir	16,000,000	55–95	Gravity
Ashland	...	Wells	Standpipe	...	...	
Barton Heights	Town	Springs and wells	Standpipe	50,000	30–60	Direct pressure
Cape Charles	City	Wells	Standpipe	50,000	60	Direct pressure
Franklin	Town	Blackwater River	Standpipe	80,000	110–125	Gravity and direct pressure
Fredericksburg	City	Rappahannock River	Reservoir	4,000,000 11,000,000	125	Gravity and direct pressure
Manchester[a]	City	James River	Standpipe	128,000	20–240	Gravity and direct pressure
Newport News	Newport News Light & Water Co.	...	Standpipe	430,000,000	200	Direct pressure and gravity
Norfolk	Norfolk County Waterworks Co. City Portsmouth, Berkeley & Suffolk W. Co.	Wells Lakes Wells	Standpipe Reservoir Standpipe	305,000	100 ... 100	Direct pressure Direct pressure Gravity and direct pressure
Onancock	Town	Wells	Standpipe	50,000	80	Gravity and direct pressure
Petersburg	City	Livetenant Run	Reservoir	3,000,000	40–150	Gravity and direct pressure
Portsmouth	Portsmouth, Berkeley & Suffolk W. Co.	Smith's Creek	Standpipe	...	100	Gravity and direct pressure
Richmond	City	James River	Reservoir and standpipe	150,000 40,000,000 9,000,000	285 15–155	Gravity
Suffolk	Portsmouth, Berkeley & Suffolk W. Co.	Smith's Creek	Standpipe	...	110–170	Gravity and direct pressure
Smithfield	Town	Creek	Standpipe	...	40–70	Gravity
West Point	City	Wells	Standpipe Cistern	65,000 20,000	70–90	Gravity and direct pressure

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[a]Now a part of the city of Richmond.

TABLE 2. (*Continued.*)—*Municipal water supplies in the Coastal Plain Province of Virginia.*

City	Length of mains (*miles*)	No. of taps	No. of fire hydrants	No. people supplied	Population of city in 1910	Daily consumption (*gal.*)	Max. capacity of pumps (*gal.*)	Domestic pressure (*lbs. per sq. in.*)	Fire pressure (*lbs. per sq. in.*)	Purification system
Alexandria	17.3	3,520	160	3,300[b]	15,329	1,000,000	2,100,000	20–35	20–35	Sedimentation
Ashland	....	....	....	....	1,324	....	....	....	....	None
Barton Heights	....	....	....	....	1,388	....	....	....	....	None
Cape Charles ..	1.5	....	20	1,100	1,948	60,000	....	25	50 (?)	None
Franklin	3.5	150	57	1,000	2,271	80,000	1,440,000	50	125	None
Fredericksburg	28.0	1,431	92	1,560[b]	5,874	....	1,000,000	40–55	55–90	Sedimentation
Manchester[a] ..	16.0	1,730	75	....	9,715	1,435,770	2,250,000	49–90	49–90	Coagulation
Newport News .		2,400	180	....	20,205	....	....	....	....	Coagulation and filtration
Norfolk	80.0	....	40	1,400	67,452	1,000,000	3,500,000	40	....	None
	....	....	....	....	....	....	22,000,000	30	....	None
	....	....	24	....	....	....	1,500,000	....	....	
Onancock	1.5	75	30	....	1,001	....	168,000	40–55	55–90	None
Petersburg	28.0	2,900	280	15,000	24,127	800,000	3,500,000	14–60	14–60	Sedimentation and coagulation
Portsmouth ...	75.0		220	....	33,190	....	10,000,000	....	....	Coagulation and filtration
Richmond	133.0	18,000	1,000	....	127,628	12,474,000	20,500,000	8–83	8–83	Sedimentation and coagulation
Suffolk			52	....	7,008	....	12,000,000	....	....	....
Smithfield				....	1,278	....	....	....	....	None
West Point ...	3.5	67	36	....	1,397	....	430,000	43	75 (?)	None

[a] Now a part of the city of Richmond.
[b] Rate payers.
[c] Population as of 1900 census.

MINERAL WATERS

The term, mineral water, as commonly used, implies either water having therapeutic value or water differing decidedly from that obtained from the springs or shallow wells of a given region. Some waters, classed as mineral, are very soft and pure, and owe the esteem in which they are held largely to their low mineralization. Others are so highly charged with various substances that they are offensive to taste and smell and have a powerful physiologic action.

As has been stated the potable underground waters of the Virginia Coastal Plain differ widely, the amount of dissolved mineral matter they contain varying from less than 50 to over 9,000 parts per 1,000,000. Many are especially light and pleasant table waters; a few are so strongly mineralized that they should be drunk only under the advice of a physician.

In general, the shallow waters differ more than the deep waters, yet they are distinguished by the predominance of calcium and magnesium salts. Some springs of shallow source contain iron and aluminum salts in sufficient quantity to have therapeutic value, others are notably free from such compounds. Most of the spring waters that have been marketed are of such low mineral content that they are to be classed as table rather than as medicinal waters.

Outside of Southampton and Alexandria counties and a part of Essex County the deep waters so far developed are characterized chiefly by the pressence of sodium and potassium salts, especially the bicarbonates. Few of these waters have been marketed, partly owing to lack of suitable transportation facilities. Some of those exploited contain sodium and potassium bicarbonates in sufficient proportion to be of therapeutic value.

The following list includes wells and springs from which water has been shipped in a commercial way at times during the past five years:

Beaufort Lithia Spring	Chesterfield County
Bellfont Lithia Spring	Chesterfield County
Buckhead Lithia Spring	Chesterfield County
Campfield Lithia Spring	Chesterfield County
Cappahonk Lithia Spring	Chesterfield County
Days Point Artesian Lithia Spring	Isle of Wight County
Diamond Spring	Princess Anne County
Erup Mineral Spring	Alexandria County
Fonticello Lithia Spring	Chesterfield County
Holly Lithia Spring	Chesterfield County
Hume Spring	Alexandria County
Landale Mineral Spring	Norfolk County
Mico Water	Alexandria County
Mulberry Island Chloride Lithia Water	Warwick County
Trepho-Lithia Water	Surry County
Powhatan Spring	Alexandria County
Virginia Lithia Springs	Chesterfield County
White Oak Spring	Norfolk County

Other springs and wells than those named have in years past furnished water for sale, and a few have been more or less extensively exploited.

The list of producers shows that mineral springs are apparently confined to a few counties, seven of the eighteen springs named being in Chesterfield County, four in Alexandria County, and two being in Norfolk County. This localization, however, simply means that most of the commercial springs are near cities in which there is a demand for agreeable drinking water. Thus the Chesterfield County springs had their commercial beginnings in shipments to Richmond, and those in Alexandria County in shipments to Washington, at a time when the public supplies of both Richmond and Washington were often turbid and were regarded with suspicion by many people. The chief market for the springs in Norfolk County is the nearby city of Norfolk.

There are few sanatoriums or large hotels utilizing the alkaline artesian waters for the treatment of disease, but a large amount of water that might be designated as "mineral" under any usage of that term, is obtainable from artesian wells along the lower courses of Potomac, Rappahannock, and James rivers, and at least one city, West Point, distributes by a public supply system an alkaline bicarbonate and sulphate water that is claimed to have decided merit in the treatment of certain disorders of the stomach, liver and kidneys.

VALUE OF MINERAL WATERS

The total value of the mineral water reported sold by the springs and wells named in the preceding list amounted to $33,000 in 1910. In addition to these sales several of the springs used large amounts in the manufacture of sweetened beverages.

DEEP WELLS IN CRYSTALLINE ROCKS.

General statement.—All the flowing wells of Tidewater Virginia tap waters that circulate through pervious beds in sedimentary deposits. Along the western edge of the Coastal Plain, a considerable number of wells have been sunk through the comparatively thin, sedimentary beds and have obtained water from the underlying crystalline rocks.

These rocks are hard, dense and without pervious beds. The water does not move through minute interstitial spaces but through relatively free passages, joint cracks which intersect the mass of the rock at various angles. The joints are of two orders, those roughly parallel to the upper surface of the rock or sheet joints, and those which are steeply inclined. Near surface the sheet joints are much nearer together and more open than at a depth of several hundred feet. The vertical joints do not disappear as rapidly with depth, but as a rule grow narrower below; yet they do not extend downward indefinitely. Since the water lies in cracks and crevices that intersect irregularly there is nothing regular in its occurrence. Success in drilling depends on striking a crevice, and the wider and longer the crevice, and the greater the number of crevices it intersects, the larger the yield. One well may find water at a certain depth, while another, a few feet distant, may go twice the depth and find none; one well may strike a crevice carrying water fed to it from some distance through a series of connecting crevices; another may strike at over 1,000 feet a crevice containing water that comes almost directly from the surface and possibly from close to the well mouth. The general character of the circulation in the crystalline rocks is shown by the accompanying diagram.

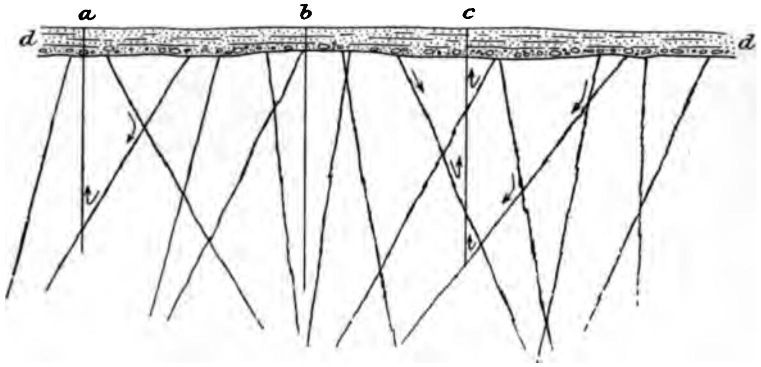

Fig. 8.—Diagram illustrating circulation of water in crystalline rocks, and well supply. (*a*) Deep well striking water that enters near well. (*b*) Deep well finding no water. (*c*) Deep well striking several crevices. (*d*) Unconsolidated material.

For the above reasons deep wells in crystalline rocks are considered by themselves, and facts relating to them are tabulated separately. Also, as the results of deep drilling in the vicinity of Richmond throw light on the occurrence of water in similar rocks and the prospects for deep wells in a strip of country extending from Maine to Georgia, some data collected in the course of field work are here discussed in detail.

WELLS NEAR RICHMOND

General conditions.—Richmond is situated at the "fall-line;" the resistant crystalline rock, a gray hornblende granite, outcrops in the bed of James River and causes rapids. In the low ground along Shockoe Creek and Gillies Creek the granite is overlain by Potomac sands and gravels; on the higher ground in the central and north parts of the city by Chesapeake dark sandy clays or marls, and along James River near the rapids by Columbia cobble beds and loams. The James is tidal to the foot of the rapids but the high Sunderland plain on which much of the city is built has an elevation of from 175 to over 200 feet. Hence, elevations of well mouths differ greatly and though a few wells were started almost directly on granite, others went through over 100 feet of loam, clay, and sand before striking hard rock.

Because of differences in surface elevation there are differences in the depth below surface at which water stands. In wells on high ground in the center of the city, water level is over 100 feet below surface. As most of the wells are pumped intermittently and few give large yields, deep well pumps are generally used. In some of the wells the pump barrel is 300 feet below the well mouth. The waters show wide differences in composition and have no general resemblance; two or three wells seem to draw on the same system of joint cracks, and one well yielded water unlike any other in Tidewater Virginia. Particulars are summarized in the accompanying table; only those wells that are of especial interest are discussed at length.

WELLS NEAR RIVER FRONT

Richmond Paper Co.—One of the first deep wells at Richmond was that of the Richmond Paper Co., drilled near the corner of Byrd and 9th Streets, in 1884. Water which rose to within 60 feet of surface, elevation 83 feet, was found at 250 feet, but it was sulphur-bearing, pitted boilers, and contained so much iron that it could not be used in bleaching rags, consequently the well was abandoned.

Albemarle Paper Co.—Another early well was that of the Albemarle Paper Co., on the river bank near Hollywood cemetery, put down like that of the Richmond Co., to get water more suitable for making paper than that obtained from the often-turbid James. It was started 10 feet above the river and found a small crevice at 225 feet from which water rose to about river level. The yield is so small, about 25 gallons per minute, that little use is made of the well except for drinking and washing filters. For boilers and for paper-making the company filters some 500 gallons per minute of river water.

Other wells.—In addition to the wells of the Albemarle and the Richmond paper companies, there are a number of others near the river, including those of Kingan & Co., the Merchants Cold Storage and Ice Co., and the Transparent Ice Co. Depths vary from 248 to 703 feet and yields from 15 to 210 gallons per minute, the deepest well giving the smallest supply. At the Kingan well, according to report, the drill dropped over 1 foot when the water-bearing crevice was reached. At these wells there is a relatively thin cover of earth, at some wells mostly made ground, above bed rock, and as suggested by Darton[a] they may yield surface water in part, though in most wells the character of the supplies indicates a deeper circulation. The waters contain enough lime and magnesia salts to make them bad for boiler use and they are utilized for condensing only. That from Kingan & Co.'s well has a sulphur odor, a flat taste, and is purgative; it is said to be so corrosive that ordinary casing lasts only 3 months and heavy galvanized casing but 3 years.

The analyst gave the following partial analysis with the results expressed as hypothetical combinations. The determinations have been recomputed to parts per 1,000,000.

Partial analysis of water from 428-foot well of Kingan & Co.

(Froehling & Robertson, analysts.)

	Parts per 1,000,000
Total solids	779.
Silica (SiO_2)	31.5
Alumina and iron oxides ($Al_2O_3 + F_2O_3$)	18.
Calcium carbonate ($CaCO_3$)	175.
Calcium chloride and sulphate ($CaCl_2 + CaSO_4$)	181.
Magnesium chloride ($MgCl_2$)	107.
Alkaline chlorides and sulphates	267.

WELLS NEAR THE CENTER OF THE CITY

Hotel Jefferson.—An interesting series of wells is that drilled on high ground, near the center of the city and northward, for the three hotels and the apartment house named below. All are 8 inches in diameter and range in depth from 365 to 702 feet. As the table shows, the depths to water and the height of the water level differ considerably, after due allowance is made for difference of elevation. The record of the Hotel Jefferson well is as follows:

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[a] Darton, N. H., Artesian well prospects in the Atlantic Coastal Plain, U. S. Geol. Survey, Bull. No. 138, p. 178.

Record of 445-foot well at Hotel Jefferson.

Group or formation	Material	Thickness	Depth
COLUMBIA			
Sunderland	"Drift soil"	41	41
	Gravel	2	43
CHESAPEAKE	Yellow clay	2	45
Calvert	Black clay	30	75
	Sand	15	90
	Sand, marine shells and a little water	12	102
	Blue clay	16	118
PRE-CAMBRIAN	Soft granite	5	123
	Hard and soft granite, water at 410 to 438 ft.	322	445

The well is said to be cased to 400 feet. The water rises to within 60 feet of surface, elevation 180 feet, but to obtain a yield of 60 gallons per minute the pump barrel had to be placed near the bottom of the well. The water is used at the table and for other purposes about the hotel but not for boiler supply. The following analysis, recalculated to express results in ionic form, was furnished by the manager.

Analysis of water from 445-foot well at Hotel Jefferson.

(Henry Froehling, analyst.)

	Parts per 1,000,000
Total solids	173.
Silica (SiO_2)	38.
Iron and aluminum oxides ($Fe_2O_3 + Al_2O_3$)	0.5
Calcium (Ca)	30.
Magnesium (Mg)	8.6
Sodium (Na)	6.2
Potassium (K)	1.2
Carbonate radicle (CO_3)	51.
Bicarbonate radicle (HCO_3)	not reported
Sulphate radicle (SO_4)	33.
Chlorine (Cl)	4.5

Chesterfield Apartments.—At the Chesterfield Apartments well, elevation 195 feet, the water, which was found at 230 feet down, stands 150 feet below surface but the yield is so free that the level is lowered only slightly by steady pumping. The apartments in 1906 used no city water at all. The following analysis, recomputed from one obtained from the manager, indicates that the well water contains bicarbonates of lime and magnesia as principal substances in solution, and considerable silica.

Analysis of water from 365-foot well at Chesterfield Apartments.

(Henry Froehling, analyst.)

	Parts per 1,000,000
Total solids	287.
Organic matter	5.9
Silica (SiO_2)	47.
Aluminum (Al)	0.5
Iron (Fe)	0.5
Manganese (Mn)	0.17
Calcium (Ca)	29.
Magnesium (Mg)	12.
Sodium (Na)	18.
Potassium (K)	3.7
Lithium (Li)	0.01
Strontium (Sr)	0.24
Iodine (I)	0.009
Bromine (Br)	trace
Arsenic (As)	trace
Bicarbonate radicle (HCO_3)	138.
Sulphate radicle (SO_4)	26.
Phosphate radicle (PO_4)	0.8
Chlorine (Cl)	6.1

Murphy's Hotel.—At Murphy's Hotel are two wells; one is said to be 450, the other 702 feet deep. The second well had not been put in service when the data for this report were collected. The first well, elevation 175 feet, struck rock at a reported depth of 125 feet. The water level is given as 100 feet below surface and the yield as 40 gallons per minute. The well is said to be cased for 350 feet, and the pump plunger is at 390 feet. The water is used for drinking and cooking, and has been bottled for table and medicinal use as Granite Lithia Water; though used in a boiler it is not satisfactory for that purpose, foaming somewhat. A series of analyses made by Otto Meyer[a] in 1904 showed the presence of radium and traces of several rare earths and of tin, copper, and nickel. The principal substances in solution, however, seem to be bicarbonates of calcium and magnesium. In general the water is much like that from the Chesterfield Apartments well. The following analysis, recomputed from that furnished by the analyst, is given for comparison.

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[a] Meyer, Otto, Radium in water from a deep well, Sci. Amer., 1904.

Analysis of Granite Lithia Water; well at Murphy's Hotel.

(Henry Froehling, analyst.)

Determination	Parts per 1,000,000
Total solids	196.
Organic matter	0.82
Silica (SiO_2)	34.4
Aluminum (Al)	0.3
Iron (Fe)	0.31
Manganese (Mn)	0.063
Calcium (Ca)	21.
Magnesium (Mg)	9.5
Sodium (Na)	21.9
Potassium (K)	5.9
Lithium (Li)	0.015
Strontium (Sr)	0.10
Barium (Ba)	0.04
Iodine (I)	0.002
Carbonate radicle (CO_3)	70.
Phosphate radicle (PO_4)	0.19
Sulphate radicle (SO_4)	24.
Nitrate radicle (NO_3)	0.15
Chlorine (Cl)	6.6

Richmond Hotel—The well at the Richmond Hotel, elevation 157 feet, struck a crevice yielding a large supply, said to be 300 gallons per minute; the depth to water could not be ascertained from the engineer in charge of the plant, but the pump plunger is 250 feet below surface. The water, which is used for all purposes, is more mineralized than that from the Chesterfield Apartments and Hotel Jefferson wells, containing more soda and potash as well as sulphates and bicarbonates.

Analysis of water from 572-foot well at Richmond Hotel.

(Froehling and Robertson, analysts.)

	Parts per 1,000,000
Total solids	702.
Silica (SiO_2)	28.
Aluminum (Al)	1.10
Iron (Fe)	0.18
Calcium Ca)	68.
Magnesium (Mg)	30.
Sodium (Na)	68.
Potassium (K)	29.
Lithium (Li)	0.01
Strontium (Sr)	0.02
Barium (Ba)	0.05
Manganese (Mn)	0.03
Iodine (I)	trace
Bromine (Br)	trace
Bicarbonate radicle (HCO_3)	182.
Sulphate radicle (SO_4)	232.
Phosphate radicle (PO_4)	0.25
Chlorine (Cl)	63.

WELLS IN THE NORTHWESTERN PART OF RICHMOND AND IN OUTLYING DISTRICTS TO THE NORTHWEST

A notable example of the uncertainty that attends the search for water in crystalline rocks is presented by three wells 550 to 650 feet deep at the Home Brewing Co. brewery, elevation 182 feet. These wells lie in a northeast line; the first well (8 inches), sunk in 1894, yields about 60 gallons per minute, and the barrel of the deep-well pump is over 400 feet below surface though normal water level is about 125 feet below; the second of smaller diameter (6 inches), 50 feet northeast of the first, sunk in 1899, gave but 5 gallons a minute when completed and has been dynamited several times at different depths without any increase in yield; the third (8 inches), 75 feet southwest of the first, is dry. The supply from the first two wells is used for condensing, brewing, and washing, but not in boilers as it scales badly. The company furnished an analysis of the water from the first well; this has been recomputed to express results in ionic form.

Partial analysis of water from 550-foot well of Home Brewing Co.

(First Scientific Station for the Art of Brewing, analyst.)

	Parts per 1,000,000
Total solids	448.
Organic and volatile	20.
Iron (Fe)	large traces
Calcium (Ca)	62.8
Magnesium (Mg)	12.6
Sulphate radicle (SO_4)	144.
Chlorine (Cl)	24.8
Nitrate radicle (NO_3)	none
Nitrite radicle (NO_2)	none

In the vicinity of the old State Exposition grounds are several wells of note. One, 8 inches in diameter, at the packing plant of W. S. Forbes, is said to be 400 feet deep and to yield, with the pump plunger 340 feet below surface, 300 gallons per minute, sufficient for all needs of the plant in 1906. The water is said to be remarkably good for boiler supply. A low mineral content is shown by the following analysis, recomputed from that furnished by the chemist.

Analysis of water from deep well of W. S. Forbes.

(Henry Froehling, analyst.)

	Parts per 1,000,000
Total solids	92.0
Organic matter	8.0
Silica (SiO_2)	15.0
Iron (Fe)	0.4
Calcium (Ca)	4.0
Magnesium (Mg)	0.2
Sodium (Na)	22.0
Potassium (K)	not determined
Carbonate radicle (CO_3)	25.0
Bicarbonate radicle (HCO_3)	not determined
Sulphate radicle (SO_4)	12.0
Chlorine (Cl)	5.3

A well said to be 385 feet deep at the Richmond Union Stock Yards, about 250 yards east-northeast of the above well, obtained but 5 gallons per minute and is said to have been affected by pumping at the Forbes plant.

Another 8-inch well not far away, that of the Southern Stove Works, about 300 feet deep, is said to yield 200 gallons per minute of an excellent boiler water that is used for all purposes about the works. In recomputed form, an analysis made by Henry Froehling for the company shows the following radicles:

Analysis of water from deep well of Southern Stove Works.

(Henry Froehling, analyst.)

	Parts per 1,000,000
Total solids	319.
Silica (SiO_2)	26.
Iron (Fe)	0.4
Aluminum (Al)	0.3
Calcium (Ca)	2.7
Magnesium (Mg)	0.7
Sodium (Na)	76.
Potassium (K)	3.6
Lithium (Li)	trace
Carbonate radicle (CO_3)	not determined
Bicarbonate radicle (HCO_3)	183.
Sulphate radicle (SO_4)	17.
Arsenate radicle (AsO_4)	trace
Nitrate radicle (NO_3)	0.8
Chlorine (Cl)	8.5
Bromine (Br)	trace
Iodine (I)	trace

Northwest of the city, in the vicinity of Ginter Park, several deep wells have been sunk which vary in the amount of water obtained. One on the estate known as Westwood went 900 feet, passing through Columbia and Chesapeake deposits to 108 feet and through granite below. The yield was but 5 gallons per minute; another on the same estate after going through 118 feet of sedimentary beds and 350 feet through granite obtained 50 gallons. At the estate known as Westbrook a well 306 feet deep obtained 50 gallons per minute of good water after going through sedimentary beds for 96 feet and granite for 210 feet; whereas another well, 322 feet deep, on the Bloomingdale Stock Farm, got 25 gallons per minute after passing through 123 feet of Coastal Plain deposits and 199 feet of granite.

The best well in this section supplies Ginter Park. It is 8 inches in diameter and 357 feet deep. Granite was struck at 123 feet. In 1906 about 60,000 gallons daily were pumped from the well for residences and for the Union Theological Seminary. The water was tried at a large laundry but proved unsatisfactory because of its hardness; it contains a considerable amount of sulphates. An analysis made for the owner, recomputed to express results in ionic form, follows:

Analysis of water from deep well at Ginter Park.

(Henry Froehling, analyst.)

	Parts per 1,000,000
Total solids	626.
Total scale-forming matter	219.5
Organic and volatile matter	6.6
Silica (SiO_2)	28.
Oxides of iron and alumina ($Fe_2O_3 + Al_2O_3$)	1.2
Calcium (Ca)	55.2
Magnesium (Mg)	11.1
Sodium (Na)	128.
Potassium (K)	8.5
Chlorine (Cl)	37.0
Carbonate radicle (CO_3)	87.
Sulphate radicle (SO_4)	263.
Nitrate radicle (NO_3)	0.18

WELLS SOUTH OF RICHMOND.

At the works of the American Ether Co. just south of the city, a 407-foot well on low ground near Almond Creek is said to have gone through "earth" for 117 feet and "rock" for 293 feet. Potomac cobble beds and soft sandstones outcrop nearby in the creek bed, and the greater part of the "earth" is probably Potomac material. The well developed a large supply, reported to have been 200 gallons per minute. This water at first was good but after some time became remarkably saline, and so corrosive that it could not be used even for condensing. The following analysis, recomputed from one made by the former chemist of the company, shows the unique character of the water:

Water from 410-foot well of American Ether Co.

(Henry Froehling, analyst.)

	Parts per 1,000,000
Total solids	1610.
Sand and silica	32.
Oxides of iron and alumina ($F_2O_3 + Al_2O_3$)	16.
Calcium (Ca)	16.
Magnesium (Mg)	8.9
Sodium (Na)	580.
Carbonate radicle (CO_3)	86.
Sulphate radicle (SO_4)	93.
Chlorine (Cl)	778.

An 8-inch well at Curle's Neck, 15 miles south of Richmond, went through Coastal Plain deposits to 311 feet, and into granite 414 feet; when completed it yielded only 9 gallons per minute. It was dynamited with the result that steady pumping for three weeks at the rate of 100 gallons a minute lowered the water level only a little. A sanitary analysis made for the owner contained these determinations:

Partial analysis of water from 710-foot well of C. H. Senff at Curle's Neck.

(J. A. Deghuee, analyst.)

	Parts per 1,000,000
Total solids	234.
Volatile solids	12.
Hardness, equivalent to $CaCO_3$, before boiling	6.0
Hardness, equivalent to $CaCO_3$, after boiling	6.0
Chlorine	37.5

EMPORIA.

At Emporia on a river terrace 40 feet above sea level, just outside the western edge of the Chesapeake deposits, is an 8-inch, 600-foot well sunk for town supply. The well entered granite at 6 feet and struck crevices at 62, 370 and 470 feet, the last being the most important. The water is reported to stand 10 feet below surface. The supply is said to be free; pumping at the rate of 100 gallons per minute lowered the water 20 feet. Only 28 feet of casing, it is stated, was put in the well. The quality of the water is reported to have been unsatisfactory and the town is supplied with river water.

PROBABILITY OF FINDING WATER BY DEEP WELLS.

The accompanying list undoubtedly omits some rock wells 200 feet deep or over that have been drilled in and near Richmond; but it probably includes the majority, and the omissions are chiefly unsuccessful wells. Drillers are liable to omit mention of dry holes when telling of the wells they have sunk, and some pursue the mistaken policy of claiming, if there is a chance of closing a contract at so much per foot with no guarantee as to yield, that they can get water anywhere. Owners do not advertise a failure and the present holder of a property may have no knowledge of a well drilled some years ago. Hence the total number of unsuccessful wells is hard to ascertain. The list tabulated, however, is long enough to serve as a basis for estimates valuable to persons contemplating deep wells for considerable supplies of water at points along the western edge of the Coastal Plain where crystalline rocks occur having the general character of those near Richmond. The facts are as follows:

(1). Of the deep wells in crystalline rocks 2 were dry or gave too little water to be of use; 7 gave, estimated or measured, 5 to 25 gallons; 16, 26 to 100; 4, 101 to 200; and 2 over 200 gallons per minute. Or, 5 gave 5 gallons or less, making the proportion of commercially successful wells over 80 per cent.

(2). Of the 22 more successful wells, 15 or nearly 70 per cent went less than 500 feet into "granite" and 1 went less than 200 feet.

(3). Of the 17 wells yielding 50 gallons per minute or over, 6 were on high ground, 6 on low ground, and 5 on hillsides, showing that yields bear little relation to the situation of wells.

ANALYSES OF WATERS FROM WELLS IN CRYSTALLINE ROCKS NEAR RICHMOND.

The following table gives all the available analyses of the wells mentioned; it includes partial analyses and determinations of chlorine, total and volatile solids, and hardness from sanitary analyses. That some of the waters may show, when the wells are pumped heavily, a very different composition from that indicated by the table is altogether possible, as the heavy pumping of wells in crystalline rocks may modify the circulation of the water for a considerable distance.

TABLE 4.—*Analyses of well water from crystalline rocks.*

(Parts per 1,000,000)

Locality	Owner	Total solids	Organic and volatile matter	Silica (SiO$_2$)	Iron and aluminum oxides (Fe$_2$O$_3$+Al$_2$O$_3$)	Iron (Fe)	Aluminum (Al)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Lithium (Li)	Arsenic (As)
Catman	O. H. Senff	234	12.0	......	......	......	......	......	......	......	......	......	......	......	......
Ginter Park	Lewis Ginter Land and Improvement Co.	620	6.6	28.0	1.2	......	......	......	55.2	11.0	......	128.0	8.5	......	......
Richmond	American Ether Co.	1610.	......	32.0	16.0	......	......	......	16.0	8.9	......	580.0	......	......	......
Richmond	Chesterfield Apartments	287.	5.9	47.0	......	0.5	0.5	.17	29.0	12.0	.24	18.	3.7	.01	......
Richmond	Hotel Jefferson	173.	......	38.0	0.5	......	......	......	30.0	8.6	......	6.2	1.2	......	......
Richmond	Home Brewing Co.	448.	20.0	......	......	tr.	......	......	63.0	12.6	......	......	......	......	......
Richmond	Kingan & Co.	779.	......	31.5	0.9	......	......	......	......	27.0	......	......	......	......	......
Richmond	Kingan & Co.	260.	58.0	......	......	......	......	......	0.8	2.2	......	74.0	......	......	......
Richmond	Murphy Hotel Co.	196.	0.82	34.4	......	0.31	0.3	.063	21.0	9.5	.1[a]	21.9	5.9	.015	......
Richmond	Richmond Hotel	702.	......	28.0	......	0.18	1.1	.08	68.0	28.0	.02[b]	69.0	28.0	.01	......
Richmond	Southern Stove Works	319.	......	26.0	......	0.1	0.3	......	2.7	0.7	......	76.0	3.6	tr.	tr.
Richmond	Southern Stove Works	271.	28.0	......	......	......	......	......	......	......	......	......	......	......	......
Richmond	State Penitentiary	190.	20.0	20.0	......	......	......	......	8.6	0.98	......	46.0	......	......	......
Richmond	W. S. Forbes	92.	8.0	15.0	......	0.4	......	......	4.0	0.2	......	22.0	......	......	......
Richmond	Virginia Union University	559.	207.0	40.0	......	......	......	......	82.0	12.0	......	7.6	......	......	......
Sherwood Park	......	66.7	......	27.0	2.9	......	......	......	7.0	1.3	......	......	......	......	......
School	Laurel Industrial School	392.	......	......	......	......	......	......	26.0	8.6	......	106.0	......	......	......

[a] Water also contains .05 parts barium (Ba).
[b] Water also contains .041 parts barium (Ba).

TABLE 4. (*Continued.*)—*Analyses of well water from crystalline rocks.*

(Parts per 1,000,000)

Locality	Owner	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Phosphate radicle (PO_4)	Bromine (Br)	Iodine (I)	Chlorine (Cl)	Nitrate radicle (NO_3)	Analyst and date
Catman	O. H. Senff	......	......	......	0.0	......	......	87.5	0.0	J. A. Deghuée
Emporia	......									
Ginter Park	Lewis Ginter Land and Improvement Co.	87.0	......	263.	......	......	......	87.0	0.18	Froehling, 1902
Richmond	American Ether Co.	86.0	......	93.0	......	......	......	778.0	......	Froehling, 1892
Richmond	Chesterfield Apartments	......	138.0	26.	0.8	tr.	.009	6.1	......	Froehling & Robertson, 1904
Richmond	Hotel Jefferson	51.0	......	33.0	......	......	......	4.5	......	Froehling, 1896
Richmond	Home Brewing Co.	......	......	144.	......	......	......	25.0	0.0	First Scientific Station for the Art of Brewing
Richmond	Kingan & Co.	105.0	......	......	......	......	......	......	......	Froehling, 1893
Richmond	Kingan & Co.	......	......	105.0	......	......	......	113.0	......	H. Bentley Smith Co., 1904
Richmond	Murphy Hotel Co.	70.0	......	24.0	.19	......	.002	6.6	0.15	Froehling & Robertson, 1904
Richmond	Richmond Hotel	......	182.0	232.0	.25	tr.	tr.	63.0	......	Froehling & Robertson, 1906
Richmond	Southern Stove Works	......	183.0	17.0	......	tr.	tr.	8.5	0.8	Froehling, 1902
	Southern Stove Works	......	......	......	......	......	......	12.0	0.25	H. Bentley Smith Co., 1904
Richmond	State Penitentiary	57.0	......	12.0	......	......	......	13.0	......	Froehling, 1903
Richmond	W. S. Forbes	25.0	......	12.0	......	......	......	5.3	......	
Richmond	Virginia Union University	96.0	......	10.0	......	......	......	35.4	68.0	H. Bentley Smith Co., 1905
Sherwood Park	......	4.2	......	......	......	......	......	......	......	Froehling, 1897
School	Laurel Industrial School	54.0	......	101.	......	......	......	96.0	.....	H. Bentley Smith Co., 1907

A comparison of the analyses shows that the total solids range from 66 to 1,600 parts per million; the calcium from 1 to 70 parts; the magnesium from 0.2 to 28 parts; the sodium from 6 to 580 parts; the carbonates and bicarbonates from 4 to 180 parts; the sulphates from 10 to 260 parts; and the chlorine from 4.5 to 780 parts. The differences are explained by differences in the underground circulation.

Changes in quality of the water.—Little can be foretold regarding the bacterial purity of the supplies from wells in granite underlying a densely populated area. Where the surface drainage is good, the soil cover on the rock thick, and the well casing tight, conditions which may obtain at all wells on high ground in Richmond, the danger of contamination is remote. But heavy pumping can produce such changes in the circulation of granite waters that the waters from wells which are seemingly not exposed to contamination may be easily polluted. After being in use a year, a deep well at Atlanta, Ga., was fouled by impure waters that may have entered the well at a depth of several hunderd feet. Hence it is advisable to analyze periodically the water of a deep well that is heavily pumped.

At Richmond the joint cracks of the granite may be filled either with river water, with ground water slightly filtered, or with water that has soaked through many feet of stratified material of varying composition. These waters may mingle after a relatively short journey under ground, or after having passed through a long series of intersecting joints and having descended hundreds of feet. A particular well may draw on one crevice or a series of connecting crevices, and hence the quality of the water from nearby wells may differ greatly.

An erratic well water, like that of the American Ether Company, obviously must be local. Various explanations have been suggested for the saline character of somewhat similar waters found in granite. A reasonable explanation for the Richmond area is that sea-water accumulated in crevices at a time when the James was salt as far west as the rapids; an alternative is derivation from water that did not come from the surface but ascended from a great depth in the earth's crust.

DEEP WATERS OF THE NORFOLK-NEWPORT NEWS AREA

General statement.—The possibility of obtaining artesian water by deep drilling near the mouth of the James first attracted attention 65 years ago when Government authorities were looking for something better than cistern or shallow well water for the supply of Fort Monroe. Since then wells have been drilled near Fort Monroe; on Back River, 7 miles north of the fort; at Newport News, 7 miles west; and in the vicinity of Norfolk, from 8 to 15 miles south and southeast. In all, fully 10 wells have been put down and not one has been considered a complete success. Some did not find flows, some found flows that were too salty for drinking or boiler supply, and some found little water.

Because a great number of successful wells have been drilled elsewhere in Tidewater Virginia, and because drillers and others have claimed that it is possible to get artesian water in the vicinity of Norfolk and Newport News, the questions whether there is a possibility of finding such water and why the wells thus far drilled have been unsuccessful merit detailed answers. Besides, although Norfolk and Newport News had in 1906 good public supplies the number of manufacturing establishments near the mouth of James River that may desire to procure for industrial purposes cheaper water than that furnished by public service systems is large, and some may attempt to find it by deep drilling. As enough work has been done to permit definite answers to some questions that would arise in the mind of any one investigating artesian possibilities, whether well owner or driller, a review of the results of deep work in the Norfolk-Newport News area and what these results indicate may save misdirected effort and wasted money. In fact, the reason for the failures to get good artesian water about Norfolk was the most important problem that came up for investigation in the course of the field work for this report.

Limits of area.—By the term Norfolk-Newport News area is meant Elizabeth City County and the south end of Warwick County, which are north of James River and Hampton Roads, and the north part of Norfolk and Princess Anne counties which lie south and southeast of the mouth of the James. The area is thus defined not because its deep wells show features which are not presented by wells elsewhere, but because of its population (over 75,000) and because it is destined to be of increasing importance as a manufacturing district. As has been indicated in the general discussion of artesian conditions in the Virginia Coastal Plain and as the accounts of work in other counties show, no flows, scanty flows, or highly mineralized water seem to be characteristic of the deep wells (more than 400 feet) in a considerable area, one that probably embraces most of Norfolk, all of Princess Anne County, the east end of Gloucester County, part of Mathews County, the east end of Middlesex County, most of Accomac and all of Northampton County.

DEEP WELLS NORTH OF JAMES RIVER

Fort Monroe.—The first deep boring in the Norfolk-Newport News area, the first in Tidewater Virginia and one of the first in the entire Atlantic Coastal Plain—the first probably being the unsuccessful well at Charleston, S. C., sunk in 1823 to a depth of 335 feet—was begun by the Government in 1864 to obtain a supply to supplant or supplement the cistern water used at the post. A previous attempt, in 1845, had reached a depth of 168 feet. In spite of the great advance in the art of well-drilling between 1845 and 1864, rigs and tools for rapid work in the soft unconsolidated beds of the Coastal Plain had not been devised at the latter date, nor were drillers generally aware of the troubles that await the man who, skilled in drilling rock wells, undertakes with such experience as a guide to sink through clays and quicksands. So it is not surprising that the well was abandoned in 1869 at a depth of 907 feet. The attempt proved of decided value to science, because the samples of the strata penetrated were examined by Rogers[a] in 1869 and later by Fontaine and Darton, and the records compiled from this study (which have been published by Darton[b]) gave the first information on the total thickness far under cover of the Miocene and Eocene deposits in Virginia. Practically, the well was a failure; several sands containing water under so low a head that it would not rise to surface may have been penetrated, but the only water noted in the record was struck in gray sand at 599 feet. This water had head enough to rise above the level of the parade ground, 3 feet above tide, but was "very saline."

In the report, dated 1876, by S. T. Abert[c] on the survey of a line to connect the waters of the Cape Fear and Neuse rivers and for a connection by water between Norfolk harbor and Cape Fear River appears this record of borings 313 feet deep at Fort Monroe. The object of the work is not stated and no mention is made of water.

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[a] Rogers, W. B., Geology of the Virginias, 1885, p. 733.

[b] Darton, N. H., Artesian Water Prospects in the Atlantic Coastal Plain, U. S. Geol. Survey, Bull. 138, pp. 168-169.

[c] U. S. War Dept., 44th Congress, 1st Session, Senate Doc. No. 35, p. 16.

Record of borings at Fort Monroe, Va.

(Authority, U. S. Engineer's Office.)

Materials	Thickness (*Feet*)	Depth (*Feet*)
Marsh soil	5½	5½
Fine clean dark sand	12½	18
Angular light-colored sand, containing coarse sand, round pebbles and mud	10	28
Sand and mud, different layers	12	40
Some stone, sand and mud	5	45
Miocene marl	200	245
(The lowest layer of the last showed some greensand and shells, next hard stone full of shells)		
Sand, bluish-gray, mixed with mud	16	261
Same, fragments of shell marl, stone harder	9	270
Softer marl, sky blue	43	313
A note says "fossil shells or continuous marine deposits were 224 feet in thickness."		

A final and decisive attempt to find potable artesian water at Fort Monroe was made in 1902. This well, sunk within the fort, started at an elevation of about 3 feet, passed through all underlying formations of the Coastal Plain, struck crystalline bed rock at 2,240 feet below mean high tide, and was sunk in this rock 8 feet, making its total depth 2,251 feet—the deepest well in the entire Atlantic Coastal Plain from New York to northern Florida. A hydraulic jet rig was used and progress was rapid in spite of the large diameter; 15-inch casing was placed at the start and 12-inch to 1,200 feet; below 1,200 feet the driller had so little trouble that 9-inch casing was used down to 2,128 feet; beyond that depth the well was not cased. Drilling began January 25, and on April 21 the well was down 2,200 feet.

Some samples of borings were saved during the progress of the work and the driller noted the general character of the beds. The type of the rig and possible errors in labelling the samples make the borings of slight determinative value, and the driller's notes are not detailed enough to be of value in discriminating formations. Hence an accurate record of this well is not available.

According to Capt. C. P. Townsley, U. S. A., while boring was in progress nothing could be told about any water bed struck except by casing to it and bailing the well. This was done at 1,317 and 2,128 feet, and at both depths the water was very salty. Evidences of water appeared at 1,520, 1,630, 1,915, and 1,939 feet, but were not tested. The head of the water at 2,128 feet was 20 feet below surface and the yield was so small that with an 8-inch boiler 21 feet long the water was easily lowered 1,000 feet in the 9-inch casing in 10 hours. The most promising horizons between 1,320 feet and 2,128 feet were at 1,640 feet and 1,915 feet. According to another officer, who happened to be at the fort in 1902 and speaks from memory, the largest flow found had head enough to just run over the casing, elevation about 6½ feet above mean tide. Efforts to develop flows of potable water at points above 2,128 feet by the use of dynamite proved unavailing; in consequence the 12-inch casing down to 600 feet and the 9-inch down to 1,200 feet were removed and no use whatever has been made of this well.

No quantitative analyses of the water from any flow appear to have been made; if any were, there is no record of them.

Newport News.—In 1882, the Old Dominion Land Company which had undertaken extensive real estate developments at Newport News, began a search for artesian water there. Unfortunately drilling began on ground 31 feet above sea level, so that the prospects for a flowing well, as subsequent work has shown, were not bright. Work started March 9, with a standard cable rig. The driller met with many accidents, in repairing some of which he had more than average good luck. At a depth of 329 feet, reached on March 31, it was found impossible to drive the 8-inch casing farther; a series of accidents followed the resumption of work with 6-inch casing, and after this casing had broken in several places, the well was abandoned on July 28, after it had been sunk 582½ feet.

The following log is compiled from the record preserved by the company.

Record of well of Old Dominion Land Co., Newport News, Virginia.

(Authority, Old Dominion Land Co.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Sand "6 kinds"	18	18
Sand and yellow clay	15	33
Sand and hard tough blue clay	36	69
Hard blue clay containing sand with shells; clay, dark blue but soft, with few shells at 106 feet	37	106
Blue clay	19	125
Quicksand	7	132
Greenish sandy clay, or marl, with numerous large shells; hard bluish sand-rock at 184½ to 186 feet; water below rock rose high enough to be seen by looking down pipe	121	253
Greenish or bluish clay, free from sand	253	270
Hard stiff tough blue clay	69	339
Bluish "soapstone"	70	409
Lighter more sandy clay which "changes" at 414 and 420 feet	14	423
Coarse sand; water rose to within 10 feet of the surface	3	426
Shells, stone and sand	2	428
Sand, which rose nearly 150 feet in pipe over night	9	437
Sand with streaks of cement rock	18	455
Sand, clayey towards bottom	38	493
Heavy brownish clay, gravelly towards bottom	14	507
Clay with stones	39	546
Clay and sand	36	582

Water was struck at two horizons in the Chesapeake group, namely, below a rock stratum at 186 feet and in a bed of coarse sand at 422 feet; neither horizon was given a good test; the water in the 422-foot bed rose perhaps 21 feet above sea level. It is unfortunate that no note was taken of the quality or volume of this water; it might have yielded a good flow at a lower elevation.

In 1907, H. E. Shimp began a well for the Old Dominion Brewing Co. at Newport News, but stopped work at a depth of about 500 feet. He did not keep a record of the section shown by the drill, and the samples he saved were lost before they could be examined by a geologist.

Back River.—A deep well was sunk in 1886 at the site of a contemplated fish factory on the tip of the sand spit, known as North End Point, on the south side of the entrance to Back River, about 7 miles north-northeast of Fort Monroe. This well reached a depth of 1,172 feet; there the drill struck a very hard stratum, which the driller thought was granite; the drill rod broke and work was abandoned. The notable thing about this well is that no water worthy of mention was found except in two beds of gravel, between 1,000 and 1,007 feet, in the Potomac group. Whether water in sufficient quantity might have been found by properly testing some of the sandy beds penetrated is uncertain. Darton has published the following record.[a]

Record of well at North End Point.

(Authority, C. C. Knox)

Material	Thickness *(Feet)*	Depth *(Feet)*
White sand and gravel	75	75
Blue clay	5	80
White sand	20	100
Thin layers of sand and blue clay	30	130
Blue or gray sand	25	155
Quicksand	10	165
Hard white sand	5	170
Loose white sand	15	185
Black marl	12	187
White sand and marl	162	249
Rock	1	250
Blue clay	17	267
Stone	1	268
Hard sand	7	275
Blue clay with thin marl layers	55	530
Hard blue clay	70	600
Quicksand	18	618
Stone or bowlder	2	620
White sand	5	625
Yellow sand	1	626
Clay and sand mixed	29	695
Gravel and clay	1	696
Hard and soft layers of blue clay	4	740
Very hard clay	8	748
Soft blue clay	165	913
Hard blue clay	7	920
Coarse sand	6	926
Sandstone	3	939
Hard sandstone	16	955
Hard sand with few gravels	18	973
Hard sandstone	27	1000
Sandstone with two veins of gravel and some water	7	1007
Alternate layers of sand and sandstone 3 to 4 feet thick	8	1015
Alternate layers of sand and sandstone 3 to 15 feet thick	65	1080
Very hard white sand	80	1100
Sandstone	155	1155
Red sandstone	5	1160
Hard sandstone	10	1170
Hardest kind of stone or granite; here drill rods broke and work was abandoned	2	1172

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[a] Darton, N. H., Artesian Well Prospects in the Atlantic Coastal Plain, U. S. Geol. Survey, Bull. 138, pp. 171-172.

Another attempt to get water on North End Point was made in 1896. R. H. Milligan, the driller, used a hollow-rod, jet outfit and had little difficulty in sinking a 3-inch hole 1,035 feet. No water that would flow at surface was found, but in conversation with the writer Mr. Milligan has stated that he thinks, in the light of his experience with deep wells at other points near the shore of Chesapeake Bay, that there are at the mouth of Back River deep-lying sands which will yield flows to a well sunk with regard to the local conditions. Though this is not impossible, the writer is inclined to regard the prospects for obtaining a good flow of potable water from depths below 500 feet at North End Point as distinctly unfavorable.

Hotel Chamberlain.—After the unsuccessful attempt in 1864-69 no further efforts to get artesian water in the vicinity of Fort Monroe appear to have been made until 1896, when a well was sunk at the Hotel Chamberlain. The well started at an elevation of 4 feet above high water, on made ground near the sea wall in the rear of the hotel, and reached a depth of 945 feet.

The following record of the well compiled from a study of the borings and notes furnished by the contractor and his foreman has been published.[a]

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[a] Woolman, Lewis, Artesian Wells, Geol. Survey, N. J., Ann. Rept. 1898, pp. 122-125.

Record of artesian well at Chamberlain Hotel, Old Point Comfort.

Material	Thickness *(Feet)*	Depth *(Feet)*
Surface sand	10	10
Sand with minute fragments of shells	20	30
Dark gray sand, spines of sea urchins plentiful	10	40
Sand, lighter in color	10	50
Sandy clay with Miocene shells	10	60
Greenish sandy clay	30	90
Sandy clay with Miocene shells	10	100
Greenish sandy clay, a few shells	20	120
Greenish sandy clay, with shells in great number	10	130
Fine dark gray sand, sea urchins spines abundant	30	160
Dark brownish sandy clay, with shells	20	180
Dark greenish clay (marine shells, Miocene age, at 190, 200, 270 feet)	100	280
Dark greenish clay, more sandy, but without shells	60	340
Dark greenish clay, not so sandy, still without shells	190	530
Dark bluish-green diatomaceous clay	30	560
Dark clay, not diatomaceous	30	590
Dark brownish sandy clay	20	610
Greenish clayey sand, with a large admixture of greensand grains and some foraminifera	50	660
Greenish sandy clay with green sand and foraminifera	50	710
Brownish sandy clay	710	800
Gray sand, mixture of greensand grains and pure quartz grains	20	820
Brownish clayey sand, also contains a mixture of greensand and quartz grains	20	840
Calcareous rock crust and pebble conglomerate with some wood and shells	10	850
Dark sandy micaceous clay	55	905
Fine gray sand	15	920
Coarse gravel, water-bearing	25	945

The well gives a rather small flow, inasmuch as the inner casing is 4 inches in diameter, of the saltest and most mineralized water yielded by any flowing well in the Norfolk-Newport News area. Though the log makes no mention of water above 945 feet, it is likely that several sandy beds were penetrated which contained water under insufficient head to flow at surface. The driller gave the estimated yield as 50 gallons per minute[a] and the head as over 17 feet above surface or about 22 feet above sea level. In 1906, according to the engineer of the hotel power plant, the flow, at surface, was "a ¾-inch pipe full" and the head was 14 feet above tide. The flow at 5 feet elevation is certainly not over 25 gallons per minute. The water has so much mineral matter in solution that it is not used except for flushing; it is too salty for drinking or for boiler use and is so iron-bearing that, though perfectly clear when fresh from the well, it soon becomes turbid and deposits much ferric hydrate. Hence it is unsuitable for bathing or for laundry use.

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[a] Darton, N. H., U. S. Geol. Survey, Folio No. 80, 1902.

The following analysis made in March, 1906, shows that though highly mineralized, the flow resembles the excellent water from artesian wells to the west in containing much soda and comparatively little lime or magnesia, in proportion to the total solids. Much of the increased mineralization is probably in the form of common salt, sulphates of soda, potash, lime, and magnesia, and iron compounds.

Analysis of water from 945-foot well at Hotel Chamberlain, Fort Monroe.

(W. H. Taylor, analyst.)

	Parts per 1,000,000
Total solids	9248
Silica (SiO_2)	14
Aluminum (Al)	23
Iron (Fe)	16
Calcium (Ca)	97
Magnesium (Mg)	44
Sodium (Na)	3268
Potassium (K)	87
Lithium (Li)	trace
Bicarbonate radicle (HCO_3)	433
Sulphate radicle (SO_4)	265
Chlorine (Cl)	4978

The following sanitary analysis, also made in March 1906, shows some additional characteristics of this water:

Sanitary analysis of water from 945-foot well at Hotel Chamberlain.

(Penniman and Brown, analysts.)

	Parts per 1,000,000
Total solids at 200° F.	9145.
Volatile solids	188.
Chlorine	4940.
Nitrogen as free ammonia	1.50
Nitrogen as albumenoid ammonia	0.16
Nitrates	trace
Nitrites	none

DEEP WELLS SOUTH OF JAMES RIVER

General statement.—In that part of the Norfolk-Newport News area south of James River and Hampton Roads, at least six wells over 200 feet deep have been sunk, but detailed records of only two are available.

However, the results of the borings are sufficient to determine the prospects for getting potable artesian water from deeply buried beds. As will be seen, though no waters are known to have been found as highly mineralized as the flows tapped by the borings near Fort Monroe, particularly the Hotel Chamberlain well, the flows all contain large amounts of solids in solution, are not what would ordinarily be called good potable water, and are not suited for boiler supply.

Virginia Beach.—One of the earlier borings for deep water in the southern part of the area under discussion was made in the winter of 1888-1889 at the Princess Anne Hotel at Virginia Beach. The elevation of the surface was possibly 7 feet. According to F. O. Clebourne, who was at the time in the employ of the company that had the work done, the well was sunk 600 feet and found no water below 73 feet. No record of the beds penetrated was kept, nor is any information available to show whether possible water-bearing beds were properly tested, but it is probable that no bed which would have yielded a flow was penetrated.

Masons Creek.—George S. Bunting states that in 1890, using a hand rig, he drilled a 1½-inch well 575 feet deep near Masons Creek, a short distance west of the present post-office of Rixton. Mr. Bunting kept no record but remembers that he cased the well to 260 feet and drilled from there to the bottom without casing. At some point below 260 feet, he struck a weak stream which did not give a flow though the elevation of the surface is not over 10 feet. A bed of shells was struck at 200 feet and shell beds or hard layers were struck at 160, 252, and 500 feet, but from 260 to 575 feet nearly all the material was fine, bluish sand.

Money Point.—South of Norfolk, on Elizabeth River, at Money Point, two deep wells were bored, but no record of either seems to have been preserved. One well has been long abandoned; the other, 562 feet deep, is said to flow 30 gallons per minute of brackish irony water at an elevation of 5 feet above tide. The flow is not suited for boiler use but is reported to be drunk as a mineral water by some people in the vicinity of the well.

Lambert Point.—In 1891 a well was completed near the pier at the Norfolk and Western Railroad terminal on Lambert Point, north of Norfolk. The well, which is close to the shore and was drilled for boiler supply, reached a reported depth of 616 feet. It struck a strong flow, 65 gallons per minute, at 610 feet in a coarse micaceous sand; and a weak flow, about 1 gallon per minute, at 603 feet in another sand bed. The driller kept a record and saved samples. Records compiled from an examination of the samples have been published by Darton[a] and by Woolman.[b] The following log is given in slightly different form.

Log of well on Lambert Point.

Material	Thickness *(Feet)*	Depth *(Feet)*
Slightly yellowish sand, shell fragments	17	17
Bluish clay, shell fragments	27	44
Gray, fine micaceous sand, shell fragments	139	183
Greenish gray, sandy clay	8	191
Gray micaceous sands	42	233
Greenish gray fine sand and clay; tough when dry (fossil shells)	31	264
Gray or bluish clay	22	286
Gray or bluish fine sand, shell fragments	69	355
Gray or bluish clay	22	377
Gray, fine sand, shell fragments	20	397
Dark gray or bluish clay	10	407
Gray moderately coarse sand, some glauconite	19	526
Small gravel, shell fragments	8	534
Gray or bluish clay	23	563
Rock, shell fragments	1	564
Dark hard fine micaceous sandy clay, well laminated	4	568
Rocky strata with thin layers of clay and shell fragments	35	603
Small gravel in gray sand, shell fragments, water	3	606
Rock, shell fragments	4	610
Gray, fine to moderately coarse micaceous sand, oyster shells	6	616

In the Norfolk folio of the U. S. Geological Survey Darton gives a list of shells and diatoms found in the borings. These show the water-bearing sand to be of Upper Cretaceous (Matawan) age.

The flow from the 610-foot sand was, when tested in 1898, 65 gallons per minute through the 6-inch casing at an elevation of 7 feet above surface, or 15 feet above mean high tide; the head was about 30 feet above sea level. Tests in 1906 showed that the well was yielding 51 gallons per minute. The temperature of the flow is 72° F.

The water is drunk by some employees at the terminal and by many people in the vicinity, but while it undoubtedly has medicinal value it is rather too mineralized for steady drinking. The prime reason for classing the well as unsuccessful, however, is that the railroad company has made little use of it except for washing cars and cleaning up around the piers. In a boiler the water foams badly and rapidly corrodes stay bolts. It probably contains considerable common salt and bicarbonate of soda (though no bicarbonates are reported) and some sulphate of soda. It contains very little lime. The following analysis was made in 1891:

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[a] Darton, N. H., Op. cit. p. 172.

[b] Woolman, Lewis, Ann. Rept. N. J. Geol. Survey, 1899, pp. 87-92.

Analysis of water from 616-foot well of Norfolk and Western Railroad, Lambert Point.

(C. W. Shepard, analyst.).

	Parts per 1,000,000
Total solids	1093.
Silica (SiO_2)	10.
Oxides of iron and alumina ($Fe_2O_3 + Al_2O_3$)	0.91
Calcium (Ca)	5.0
Magnesium (Mg)	1.7
Sodium (Na)	415.
Potassium (K)	21.
Sulphate radicle (SO_4)	43.
Carbonate radicle (CO_3)	245.
Chlorine (Cl)	351.

Whether better water could have been had by deeper drilling is doubtful. It is barely possible that water a little less mineralized might have been found above 1,000 feet; below that depth, judging from the results of other borings, it is likely that the water obtained would have been more saline.

Moore's Bridges.—A well was sunk at Moore's Bridges, 5 miles northeast of Norfolk near Diamond Springs post-office, by the Norfolk City Water Department in 1890, to a depth of 730 feet; it found salty water. The next and the most important well in the southern part of the Norfolk-Newport News area was sunk in 1896-98 at Moore's Bridges, to test all the water-bearing sands found down to bed rock. A standard cable rig was used. Partly on account of the rig, work progressed slowly, and operations were finally abandoned at 1,760 feet below surface, elevation about 8 feet above sea level.

The following log has been slightly changed from the form in which it was published by Woolman[a]. References to the microscopic organisms noted by Woolman are omitted.

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[b] Woolman, Lewis, Ann. Rept. N. J. Geol. Survey, 1899, pp. 92-102.

Record of Norfolk City Well near Waterway.

Material	Thickness *(Feet)*	Depth *(Feet)*
Light buff sandy loam	3	5
Fine light sand	13	18
Sand, water-bearing	3	21
Bluish clay, fossiliferous	44	65
Bluish clay, not fossiliferous; small streak of gravel at 80 feet	20	85
Gray clayey sand and gravel; scallop shell (Miocene), at 105 feet	20	105
Gray clayey sand, fossiliferous and containing rather large white quartz pebbles at 110 to 115 feet. *Rangia cuneata* shell at 125 feet	20	125
Gray clayey sand, with comminuted shell	40	165
Fine bluish clay, scallop shell (Miocene) at 185 feet	85	250
Gray clay, with much sand; full of shells about 5 inches long, boring had to be cased	10	260
Dark greenish sandy clay	25	285
Soft clay which ran into boring	20	305
Greenish gray clay	5	310
Gray sandy clay, very sandy clay had to be cased off, 310-320 feet	65	375
Light fine less sandy clay	70	445
Light gray fine clay, comminuted shell at 465-475 feet	135	580
Slightly lighter, fine clay, called "brown mud" by driller	45	625
Green sand marl (glauconite) mixed with white quartz sand	10	635
Dark greenish clay	30	665
Dark sticky hard clay	20	685
Gray sticky hard clay, with glauconite described by driller as "sand gravel and marl"	20	705
Lighter gray sticky fine clay; much comminuted shell at 715 feet	23	728
Gray sand, small flow of salty water	2	730
Soft sandy clay, with much comminuted shell	5	735
Small gravel (and clay), flow of salty water	10	745
Very sandy greenish clay, micaceous sand, fossil shell Upper Cretaceous at 755 feet to 765 feet; water at 740 to 750 feet	20	765
Gray micaceous sand with a little glauconite; flow of water at 780 to 783 feet[a] Upper Cretaceous shell	18	783
White, very light gray, sticky clay	2	785
Gray quartzose sand, some mica, no glauconite; slightly salty water, flow 35 gallons per minute at surface, 786 to 805 feet	30	815
Decidedly darker gray sand, no glauconite	20	835
Lighter gray sand	35	870
Gray very sandy clay	20	890
Black sticky mud (no sample)	8	898
Clayey sands or alterations of gray sands and clays, sands micaceous; lignite at 925 and 965 feet, quartz pebbles at 925-935 feet; slightly salt water; flow 75 gallons per minute at 950 feet; 10 gallons per minute at 975 to 980 feet; 15 gallons per minute at 985 feet	93	991

[a] All sands between 750 and 783 feet are said to have flowed into the well. This indicates the sands were loose, but not, as Woolman suggests, strongly water-bearing.

Record of Norfolk City Well near Waterway—(Continued).

Material	Thickness *(Feet)*	Depth *(Feet)*
Slightly yellowish (greenish when fresh) sandy clay	42	1,033
Gray sands, some micaceous, pebbles at 1,060-1,070 feet; flows of salt water, 25 gallons at 1,038 feet; 150 gallons at 1,070 feet	45	1,078
Gray sands, clayey and micaeous above 1,100 feet	32	1,120
Darker gray fine to coarse sands, heavy pebbles at 1,130 feet; coarse gray sand lignite at 1,160 feet; heavy pebbles and water at 1,190 feet, yield of water by bailing 350,000 gallons per 24 hours; said to have been fresh at first, afterwards salty	30	1,190
Reddish and reddish yellow or buff clays and clayey sands, heavy pebbles at 1,210 feet	40	1,230
Dark fine clay and micaceous sand (?) called "black marl" by driller but not a greensand (glauconite) marl; lignite at 1,250 feet	25	1,255
Slightly yellowish-olive somewhat micaceous sand; "some water"	35	1,290
"White marl" (no sample)	5	1,295
Reddish yellow and gray clays and sandy clays called "red marl," but not glauconite; fossil shell (Upper Cretaceous) reported from 1,320 feet	35	1,330
Alternations of sands (micaceous 1,320-1,340 feet; not micaceous below) and clayey sands varying from white or light gray to yellowish in color; heavy pebbles at 1,470-1,480 feet and 1,540-1,570 feet. Clay beds (no samples), 1,356-1,358 feet; 1,400 to 1,410 feet; 1,557-1,560 feet; 1,568-1,571 feet; lignite at 1,500 feet; salt water, good flow at 1,480 feet; flows at 1,510-1,517 and at 1,535 feet	250	1,580
Dark slightly variegated clay	20	1,600
Reddish or slightly reddish coarse sands and clayey sands; beds of clay (no samples) probably not glauconitic but bluish when wet, at 1,640-1,647 feet; 1,650-1,654 feet; 1,677-1,680 feet	80	1,680
Dark coarse very sandy clay, slightly variegated with red, similar to that from 1,580-1,600 feet, but more sandy; probably dark clay beds at 1,683-1,685 feet and 1,693-1,695 feet	20	1,700
Reddish variegated clay	42	1,742
Loose sand which ran up 150 feet in casing; evidently water-bearing (no sample)	20	1,762

Darton[a] states that water beds were found at 783, 805, 950, 975, 984, 1,038, 1,072, 1,190, 1,220, 1,227, and 1,480 feet, and at the bottom, which yielded from 10 to 150 gallons per minute under the pump. One or two of the beds may have given more but no flow of fresh water was struck. The water from the 1,190-foot bed did not quite overflow; at 1,220, 1,227, and several points below small volumes of salt water were found, and at

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[a] Darton, N. H., Geologic Atlas of United States, Norfolk Folio, No. 80, p. 4.

1,480 feet a large volume of very salt water. Twelve-inch casing was used to 778 feet, 10-inch to 1,208 feet, 8-inch to 1,539 feet, 6-inch to 1,730 feet, and 4½-inch to 1,750 feet.

The well was dynamited at 1,072 feet and possibly at other points, and nothing definite is known of the source of the present flow. It is supposed to come from about 680 feet but the temperature indicates a greater depth. The yield amounts to 75 gallons per minute through a 4½-inch pipe, the well mouth being 11 feet above tide. The flow, said to have a head of 20 feet, has a temperature of 76° and a decided sulphur odor, is saline and contains sodium bicarbonate as shown by the following field assay made by the writer in November, 1906.

Field assay of water from deep well at Norfolk City pumping station.

	Parts per 1,000,000
Iron (Fe)	trace
Calcium (Ca)	little
Chlorine (Cl)	1,000.
Bicarbonate radicle (HCO_3)	620.
Sulphates, as SO_4	110.
Total hardness, as $CaCO_3$	7.5

A sample collected in November, 1904, and analyzed by Dr. Sheperd, city bacteriologist of Norfolk, contained 920 parts of chlorine per 1,000,000.

Had the well been sunk deeper, even to bed rock, the probabilities are that all water found would have been more saline than that struck at 1,072 feet. In fact salinity apparently increased with depth. The sodium chloride content for three flows, from partial analyses made while drilling was in progress, as given by Darton in the Norfolk folio of the Geologic Atlas of the United States, compare thus:

Sodium chloride and total solids in deep waters from Norfolk City well.

(Henry Froehling, analyst)

Parts per 1,000,000

Flow	Total mineral matter	Sodium chloride
730 feet	2,578	1,926
1,038 "	3,345	2,723
1,070 "	3,652	2,830

In 1906 the flow ran into the clear water basin at the pumping station. There is of course not the slightest possibility of the well water being polluted.

COMPARISON OF RECORDS.

The scanty observations recorded by some drillers and the varying terms used in describing what were probably similar deposits makes correlation of the well records difficult. Samples saved from the wells at Fort Monroe, Moore's Bridges and Lambert Point were examined by Woolman and by Darton and the records prepared by them were based largely on the samples. The best series were from the Hotel Chamberlain and Norfolk City wells. In all except the Norfolk City well water-bearing beds may have been passed which were not noted by the driller.

A comparison of the records shows that the Chesapeake group in the Norfolk-Newport News area, considering its thickness, is very poor in water-bearing beds. There is one midway in it at the last well at Fort Monroe, one at the base in the old well, and one near the base at the Money Point well. The Pamunkey is thin and unimportant. Water was found near the top in the last Fort Monroe well and probably at Newport News. Upper Cretaceous beds proved prolific water carriers at the Hotel Chamberlain. Fort Monroe (1902), Lambert Point, and the Norfolk City wells. The Potomac group at Fort Monroe was fully 900 feet thick, and contained many water beds.

The least mineralized water found below 200 feet by any well is the Lambert Point flow, which according to the 1891 analysis contained 1,091 parts per million of total solids of which 518 parts per million, according to a hypothetical combination given by the analyst, were sodium chloride. In comparison, the 738-foot flow of the Norfolk City well, which is presumably from the same group of beds though not necessarily from the same horizon, contained 1,923 parts per million of sodium chloride. Here is a decided increase of salinity in a distance of 10 miles eastward, a fact in harmony with the general increase of mineralization of deep waters toward the ocean, elsewhere noted. The Lambert Point well is the farthest west of the wells in the Norfolk-Newport News area south of James River, its water is least mineralized and comes from the Upper Cretaceous at a depth of only 616 feet. These details are important.

The results obtained from the work here noticed indicate that it is altogether probable that waters found between 500 and 700 feet at Newport News will be less saline than those from beds of corresponding age at Fort Monroe and in character will approach the Lambert Point flow. North of James River the best chances for finding flows of potable artesian water near Newport News are at elevations less than 20 feet and at points west of a north and south line running through that city: eastward, probabilities rapidly become unfavorable and in the eastern part of Elizabeth City County deep drilling will probably prove a waste of time and money.

South of James River the best prospects are west of a north-northwest line through Lambert Point with diminishing chances of success eastward. In Princess Anne County efforts to get good water by deep boring will, in all probability, be of no avail, and within the city limits of Norfolk there are small chances of getting water better than the Lambert Point flow at depths below 500 feet.

CAUSES OF MINERALIZATION.

The Norfolk-Newport News area, as previously stated, is not exceptional in the character of its deep waters. In fact it forms part of a much larger area which may include the whole Eastern Shore of Virginia and certainly extends south and east into northeastern North Carolina. The possible causes of the high mineralization, saltness, and other characteristics of the deep waters of this large area will not be discussed here. It is enough to say that the saltness is not due to sea waters included in the beds when first deposited, since the flows do not resemble sea water in composition, and there are salt flows from Potomac formations, which are not marine. The increased mineralization probably results from several causes. One is difficult circulation due to the decreased permeability of the water beds down the dip; for horizons which yield bountiful flows farther west are not water-bearing in this area and at some localities, as at Back River, water-bearing beds seem to be lacking through 1,000 feet of strata. At the same time, since coarse sands yielding free flows, under good heads, of water too saline for boiler use have been encountered, the texture of the beds can not be the sole factor. Besides increased fineness of sediments, or pinching out of water beds locally or to seaward (causing slow circulation and ponded water), the more effective factors have been long confinement under pressure and, particularly, the invasion of salt water from up the dip in times when the coast was depressed below its present level. Corresponding beds to the west have been more flushed by downward percolating rain water since the last elevation, hence now contain relatively fresh water.

FRESHENING OF DEEP WATER.

That wells which yield saline water may, by heavy pumping or unrestricted flow, come to yield fresh water is a possibility that has attracted the attention of geologists. Instances of freshening have been reported but whether or not the improvement was due to the replacement of the contained salt water in the water bed by fresh water from up the dip can not always be determined from the evidence available. Fuller[a] noted some instances of a change from salt to fresh water in wells near the mouth of Cape Fear River, N. C., and concluded that the freshening represents such a replacement.

In objection to this view it may be said that a well might penetrate a bed containing salt water and one containing fresh. In such a well the yield of the water beds, the heads of the water they contain, the tightness of the well casing, and the possible clogging of the well at one horizon by sand, are factors that would determine the quality of the water obtained.

Permanent freshening with no marked decrease in flow has not been observed, so far as known at any well in the Norfolk area, but it is possible that there has been a very slight decrease in the mineralization of the water from the Lambert Point well, though analyses extending over a period of 18 years, during which time the well has flowed without restraint, show little betterment. A marked decrease in mineralization and in volume of flow was noted in June, 1909, but after the flow was restored by cleaning out the well its quality was substantially the same as before. The important determinations, total solids and chlorine, are given below:

Variations in mineralization of water from Lambert Point well.

(Parts per 1,000,000.)

Date	Total solids	Chlorine
1891	1,091	350
1906, Dec. 15	1,421	290
1909, June 17	86	23
1909, July 6	1,128	290

The freshening of the water in June, 1909, was evidently due to the main flow being cut off or greatly reduced by sand; the quality of the water as shown by the analysis dated June 17, given in table 10, is not at all like that of any deep well in the Norfolk-Newport News area, but resembles that from wells less than 200 feet deep. There was evidently no detectable change in chlorine content between 1906 and 1909; the indicated change between 1891 and 1906 rests on a single analysis, and is not large enough to be entitled to much consideration. Making allowances for differences in analytical methods and in statements of results by different chemists, the variation in chlorine content between 1891 and 1909 is so small that one may fairly assume that it would not pay to drill a well to a known salt-water horizon in the Norfolk-Newport News area in the hope that by unrestricted flow the water would become fresh enough for boiler use.

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[a] Fuller, M. L., Instances of Improvement of Water in Wells, U. S. Geol. Survey, Water Supply Paper, 160, pp. 96-99.

SUMMARY.

(1). In the Norfolk-Newport News area the prospects for obtaining good boiler water by deep drilling are poor.

(2). The chances of obtaining such water improve west of Newport News and Elizabeth River.

(3). Mineralization increases toward the east and with depth.

(4). Better water is found above 1,000 feet than below.

(5). The high mineralization of the deep waters has been caused by factors affecting a large extent of country.

(6). A flow of salty water may become fresher by allowing the water to run without hindrance, but in this area the decrease in salinity is too gradual to be worth consideration in determining the sinking of a deep well as a business venture.

UNDERGROUND WATER SUPPLIES BY COUNTIES

ACCOMAC COUNTY

General description.—Accomac is the larger of the two counties covering the Virginia portion of what has long been known as the Eastern Shore, the peninsula between Chesapeake Bay and Atlantic Ocean. The county is about 45 miles long by 15 wide and has an area of 478 square miles. Although in 1900 but two counties in the state had a larger population per square mile, there was not within the county in that year a settlement with a population of over 1,000 people. The two incorporated towns, Onancock and Bellehaven, had populations of 938 and 331.

The surface has slight relief and is monotonously level. Except in some small areas, elevations are below 25 feet, hence the surface is mostly part of the Talbot terrace.[a]

There are few fresh water streams of any size or even stream valleys. Along the ocean side and on many stretches of the bay side are wide expanses of salt marsh or land flooded at high spring tides. The ocean side is characterized by many off-shore sandy islands of the barrier beach type, of which Chincoteague is the most important. Back of these islands are shallow bays where miles of mud or sand flats lie bare at low tide.

The surface soil, a light warm sandy loam, is in many places underlain by from 2 to 6 feet of buff or light-brown sandy clay and this in turn by a varying thickness of coarse white, gray, yellowish or occasionally brownish sand that contains scattered lenses of gravel and thin beds of light-colored clay with darker beds below.

UNDERGROUND WATERS

Distribution and quality.—The Eastern Shore term for a water-bearing horizon is a spring, and drillers speak of the first, second, third, and fourth "springs" found at such and such depths; the "first spring" being at the water table. The fluctuations of the water table from rainfall are spoken of as the rise and fall of the "springs" and on Chincoteague Island one is told that "the water springs" (stands higher) in shallow wells after wet weather. The "first spring" is in the yellow Columbia sands. As a rule, the second, third and fourth "springs" are in the beds that underlie the yellowish or reddish beds of the Columbia, though in places the second "spring" is the sand and gravel at the base of the light or bright-colored beds, separated from the first "spring" by clays or loams yielding little or no water to a driven well.

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[a] The author believes that the terrace here termed the Talbot is in large part to be correlated with the Pamlico of North Carolina.

The first "spring," the water not being confined, affords no flowing wells, though shallow dug wells in hollows may be full to overflowing after prolonged rains. The "springs" below, the water being confined under relatively impervious beds of clay yield in many places flowing wells at low elevations.

The quality of the underground water varies. Nearness to inlets from the sea or bay is an important factor in the quality of supplies. In general, the water from dug wells or from pumps driven to the first "spring" does not contain as much lime or magnesia as that from the second or third spring; it is also less alkaline. On the other hand, it is rather more likely to be iron-bearing. Probably the best water for general use comes from 50 feet or more below surface. Along the coast and on the islands many shallow wells yield brackish water and many are salted by unusually high tides. Wells 25 to 200 feet on small islands are more apt to yield brackish water than those on the mainland.

Springs.—There are no true springs of commercial importance. In places water seeps from the creek banks at points where the water table curves down to the creek; such springs often disappear in dry weather. There are, however, springs of perennial flow and a few are used for household supply. What is said to be the largest spring in the county flows from the foot of a bluff on the shore of Chincoteague Bay, 2 miles north of Sinnickson. Another spring at Drummonds Mill, near Grape post-office, was once of local repute because its iron-bearing waters were believed to have medicinal value.

Wells.—The commonest type of well is a shallow hole dug to the "first spring." The deepest dug wells are near Assawoman, where some go 40 feet to water, but the depth of the average dug well in the county is about 10 feet. Buckets with chain or rope, or windlass or pulley, lift the water from the well. Here and there are wells with the old-time sweep and bucket. The perishable nature of wood casing and the many sanitary objections to it have led to the introduction of tile, 20 to 24 inches in diameter. The labor cost of digging a well varies according to the depth to water, but seldom exceeds $5.

Driven wells or "pumps" as they are called, are easily sunk, much used, and give satisfaction. Wells to the "first spring" are often put down by the owner, a piece of 1½-inch or 2-inch pipe with a pointed cap being driven by a maul; if the clay subsoil is tough, a hole may be bored through it with an earth auger. Many wells over 20 feet deep are sunk by the jet process, as are nearly all wells over 50 feet deep. Most drillers use hand-power rigs, though the driller who has done the most work in the county has a small gasoline engine. Probably no county in Tidewater Virginia has more driven or drilled wells 50 to 100 feet deep. Their usual diameter is 1½ to 2 inches. For such wells hand-power pumps, either iron pitcher pumps, wood pumps, or force pumps, are generally employed, though many residences have wind mills. One driller in 1906 gave the following as his usual charges for putting down driven wells, or, as it is called, "cutting pumps."

10-foot well	pitcher pump	$8
	wood pump	$12
30-foot well	wood pump	$20
	force pump	$22
50-foot well	wood pump	$30
	force pump	$32
100-foot well, no pump, about		$75

This driller has sunk a 103-foot well and finished it with a pitcher pump for $50. It is usually understood that the owner will furnish free such extra labor as a driller may need.

LOCAL SUPPLIES

New Church.—At this village near the northern line of the county, dug or driven wells to the "first spring" average 12 to 15 feet deep. The water is generally hard. In some wells it is so iron-bearing that it is not fit for laundry use, while in others it contains little iron. The "second spring" from 30 to 35 feet, is also decidedly iron-bearing in most wells. The "third spring" has been developed by two wells, both of which yield excellent water. One of these, owned by J. E. Johnson, is 125 feet deep and draws on water in a bed of shells in dark bluish sand; this water rises to within 4 feet of surface. An ordinary pitcher pump easily supplies 8 gallons per minute. The record of the beds penetrated is as follows:

Record of well of J. E. Johnson, near post-office at New Church.

(Authority, I. B. Clark, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Soil	1	1
Pipe clay (light gray clay)	7	8
Yellow sand, small pebbles and gravel with plenty of water of poor quality, "first spring"	6	14
Blue mud	30	44
Sand, a little water, "second spring"	3	47
Blue mud	73	120
Dark, bluish sand with small shells, excellent water, "third spring"	5	125

The owner has at his saw-mill nearby a well to the "second spring" which yields a fair boiler water, and a well to the "first spring" at his store. Results of field tests of samples from a 12-foot driven pump and the 135-foot well at J. E. Johnson's store, and the 34-foot well at the mill, made by H. N. Parker, are given in table 7, to show how great are local variations in quality.

The tank of the New York, Philadelphia & Norfolk Railroad is supplied by a pump drawing from eight 2-inch points driven 30 feet, or to the "second spring." These yield fairly good boiler water.

Franklin City and Greenbackville.— These villages are on or near a strip of salt marsh bordering Chincoteague Bay. At Franklin City there are no dug wells as the town site is inundated at high tides. Pumps to the "first spring" yield brackish water. Fairly good water, which rises to mean high tide level, is obtained by driving 30 to 70 feet.

At Greenbackville, where fresh water is found at 6 feet and even less, pumps are driven 10 to 45 feet and obtain water of varying quality. That from some wells is high in iron, lime, and chlorine; that from others is less mineralized. The water tank of the New York, Philadelphia & Norfolk Railroad is supplied by three driven wells 25 feet in depth, which are said to yield a sufficient supply of satisfactory boiler water. At a canning factory nearby, water is obtained by wells driven 15 feet. One well was driven 80 feet but obtained no water below 50 feet. In the thickly settled portion of the village the "first spring" at 5 to 15 feet, supplies most pumps, but is regarded by local physicians with suspicion on account of possible pollution from stables and privies; much of the water obtained at 10 to 12 feet is iron-bearing and brackish. According to T. F. Mumford, who has driven many wells, excellent water is obtained from some wells not over 40 feet deep, while others yield water containing considerable quantities of mineral salts, chiefly composed of lime, iron, and sodium.

Dr. H. C. Mallory gave the writer samples of residue obtained by evaporating water from three wells at Greenbackville: Those of Elihu Tull, 18 feet; James Chapman, 22 feet; and J. T. Sharpley, 45 feet. These were qualitatively analyzed by R. B. Dole, assistant engineer of the Water Resources Branch of the U. S. Geological Survey, with the following results:

Analyses of residue from well waters at Greenbackville, Va.

	E. Tull	J. Chapman	J. T. Sharpley
Silica	high	moderate	moderate
Iron	high	moderate	low
Calcium	high	moderate	low
Magnesium	high	low	low
Sodium	moderate	moderate	trace
Potassium	low	low	moderate
Sulphates	moderate	low	low

Field tests of samples from the wells of Elihu Tull (18 feet) and J. T. Sharpley (45 feet) at Greenbackville, and James Chapman at Franklin City, showed notable variations in mineralization. (See table 7.)

Drillers charge about $25 for a 40-foot well and $35 to $70 for a 70-foot well.

Chincoteague.—Chincoteague Island and its larger neighbor, Assateague, are growing in popularity as summer resorts and are known to many sportsmen for the duck-shooting on Chincoteague Bay and its connected inlets. The village of Chincoteague has a summer population of over 1,500, and the question of water supply is of increasing importance. Both islands are low and sandy—a succession of beach ridges under 10 feet high, except for a few small dunes that may rise above 15 feet. On Chincoteague water is obtained from dug and driven wells 3 to 14 feet deep, the best water being found in white sand in the higher parts of the island. Only two attempts to find water at greater depth, previous to 1906, are reported. James Williams drove 70 feet on the outskirts of Chincoteague village some years ago without result, and the United States government attempted to get deep water at the lighthouse on Assateague. This last trial was abandoned when a pipe had been driven to a reported depth of 135 feet.

The quality of the water from the dug and driven wells varies considerably, and is said to be better after a long spell of wet weather than during a drought. The water level in the interior of the islands fluctuates a couple of feet with the seasonal variations of rainfall, and when the "springs are low" in dry weather many wells yield brackish water.

In the village of Chincoteague driven wells are almost the sole source of supply, not over 25 cisterns being reported in use in 1906. Near the water front many wells have been salted by unusually high tides. Much of the well water is highly colored by iron or organic compounds, but there is great irregularity in this respect—the water from wells less than 20 feet apart differing decidedly in appearance. A sample said to represent a fair average of the wells in town was taken from a tank at the store of D. J. Whealton. This water is drawn by a wind pump from three points driven 14 feet. The results of a field test are given in table 7.

As the demand for domestic purposes is increasing, and present sources of supply at Chincoteague are not altogether satisfactory, the possibility of getting better supplies by wells deeper than any yet sunk calls for investigation. However, it is not likely, in view of what is known regarding the deep flows of the mainland, that good water will be found at great depths, 1,000 feet or more; and the prospects for potable water between 100 and 1,000 feet are not promising.[a]

With ordinary precautions against pollution the driven pumps now used will suffice for isolated dwellings. The use of water from surface ponds near dwellings for "drinking" (floating) oysters is decidedly objectionable.

Wells on the bay side at Saxis, Belinda, Marsh Market, and Grotons.—A large number of wells have been driven near Saxis, Belinda, Marsh Market, Grotons, and Justisville and a few of these flow. Details regarding some appear in table 5. The supplies are in some places excellent and in others so hard and iron-bearing as to be unsuited for household use. One well on the steamboat pier at Saxis found water in a bed of coarse gravel under 2 feet of bluish sand indurated enough to be called rock by the driller. The record is as follows:

Well of Baltimore, Chesapeake & Atlantic Steamboat Co., at Saxis.

(Authority, I. B. Clark, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Water	6	6
Blue mud	87	93
Bluish rock	2	95
Gravel, with pebbles as large as marbles, water-bearing	2	97

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[a] A deep well is reported to have been drilled in 1910 for a projected fish factory on Assateague Island. The depth of the well and the quality of the water found are not known to the writer.

The water, which is of good quality, rises to tide level.

At a saw mill half a mile east of Belinda belonging to Ross & Hall, two 1½-inch wells were driven, 44 and 46 feet respectively, to the "second spring" to get enough water for a 50-horse power boiler. The water was hard and formed scale. Wells to the "first spring," 8-10 feet, did not get water enough. Half a mile northwest of Belinda a well was driven to the "third spring" finding water in a bluish gray sand containing small bivalve shells. Those washed up by the drill were not identifiable.

A well at the oyster house of M. L. Hall on the outer edge of a wide strip of marsh facing Mesango Creek was driven 64 feet, stopping on "rock." It yields brackish water high in iron that is used for washing oysters and has been tried in a boiler. An 84-foot well at Belinda post-office found water which rose to above tide level, but contained so much iron as to be unfit for domestic use.

At the mill of J. A. Hall at Marsh Market a 2-inch well driven 92 feet struck water which rose to 4 feet above tide or 1 foot below the surface. The yield was insufficient and a 1½-inch well had to be sunk to the sands at 48 feet to get water enough for a 50 horse-power boiler.

Wells on the bay side farther south.—Farther south on the bay side of the county a considerable number of flowing wells, ranging in depth from 36 to 160 feet, have been sunk along Muddy, Hunting, Deep, Chesconnessex, Onancock, Pungoteague, and Nandua creeks, there being probably 30 on Hunting Creek alone. As a rule these wells yield good water which may have (when fresh from the well) a faint odor of sulphur; in places the water is slightly hard and iron-bearing. Details of many wells are given in table 5.

A well on Muddy Creek near Mearsville showed the following succession of materials:

Record of well of W. J. Somers, one mile south of Mearsville.

(Authority, I. B. Clark, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Soil	1	1
Sand	4	5
Blue mud	75	80
Bluish sand, poor water	4	84
Blue mud	33	117
Sand with small shells, good water	1	118

This 1½-inch well, according to the driller, flows at an elevation of 6½ feet above tide 1½ gallons per minute.

Between Chesconnessex and Deep creeks, where the ground is so low that shallow wells are liable to be salted by high tides, several deep wells have been driven yielding water of fair quality. The following succession of beds was reported from a well near Deep Creek:

Record of well of Bailey East, one-half mile north of Chesconnessex.

(Authority, Bailey East, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Soil	1	1
Yellow sand	19	20
Black, bluish, and slate-colored marsh mud	19	39
Bluish gray sand; a little water	1	40
Loam with smooth pebbles, yellow, gray, black and white; water at base	3	43
Bluish sand, water at base	32	75
Coarse gravel, no large stones; water	4	79
Bluish sand, with shells at 95-99 feet; water at 37 and 100 feet	58	137

The water from all the four "springs" rose to the level of mean high tide, or within 18 inches of it, and is slightly irony.

Onancock, on Onancock Creek, has a public supply system, but most persons get water from driven wells, many of which go only to the "first spring" at 16 feet. In 1906, seven 2-inch wells at the town waterworks reached various depths—two 16 feet, two 30 feet, and three 50 feet. They were fitted with slotted brass strainers and were, except one, connected to a triplex pump driven by a 7 horse-power gas engine that lifted the water to a 50,000-gallon tank on a steel tower 65 feet high. The wells are driven over a roughly circular area 90 feet in diameter, about 18 feet above mean high tide. The head of the water in the points is said to be about 5 feet above tide. In addition, water is pumped from a dug well 20 feet in diameter and 16 feet deep, in which one of the points to the 50-foot sand is driven. The yield from the driven wells is small and much of the water used comes from the dug well, which serves both as well and reservoir. The total yield is given as 35 gallons per minute.

The following record of one of the pumping-plant wells was given from memory:

Record of well at waterworks, Onancock.

(Authority, F. A. Merrill, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Soil	1	1
Red clay	3	4
Yellowish sand at base, gravel containing pebbles one-half inch in diameter; water-bearing	12	16
Bluish sand and mud	14	30
Bluish gray sand, water	5	35
Blue mud	15	50
Coarse gray sand with pebbles up to one-half inch; water	5	55

A field assay of water drawn directly from the points, and another, by H. N. Parker, of water presumably taken from the dug well are given in table 7.

The water is used in the boiler of vessels belonging to the State oyster navy and in those of steamers running to Baltimore. The bacterial purity of the supplies from the 50-foot bed should be unquestionable but in 1906 contamination of the open well was possible.

In 1906, about one-third of the estimated population, 1,200 people, used this water, the remainder getting supplies from driven wells 16 to 25 feet deep. The yield of the 25-foot wells was said to be small, but the water was pronounced very good.

Several attempts to supply the town from other wells than those now used have been made and two deep wells have been sunk without success. One drilled in 1890 by H. K. Shannahan found water at 90 and 140 feet, and more below to a depth of 486 feet. The casing was broken in an attempt to withdraw it, and the water from the 140-foot sand which rose nearly to surface was used for a few years by means of a wooden pump. The yield was 5 to 10 gallons per minute. The water was not liked because of its "sulphur" odor and the well has been abandoned for years. Another well was sunk in 1895 to about 600 feet without getting a satisfactory supply.

The following incomplete log of the well drilled by Mr. Shannahan is from that published by Darton.[a]

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[a] Darton, N. H., Artesian well prospects in the Atlantic Coastal Plain, U. S. Geol. Survey, Bull 138, p. 131.

Partial record of well at Onancock.

Material	Thickness (Feet)	Depth (Feet)
No record	150	150
Shells in gravel and sand	25	175
No record	5	180
Fine sand; no water	25	308
Hard rock 9 inches: clay 2 inches: rock 5 inches; clay 5 inches	2	310
Clay and sand	23	333
Clay and sandy clay	147	480

The 50-foot sand tapped at the waterworks is reported to be water-bearing and to yield no water within short distances. The flowing well of H. L. Hurst, on the edge of the creek, 50 yards from the waterworks, is only 34 feet deep and evidently taps this sand.

At Finney, back of Onancock, are several wells over 50 feet deep. The 83-foot well of W. T. Rogers, according to the owner, went through hard black mud from about 50 to 75 feet, below that dark sand, and below that light sand containing half-inch pebbles. The water does not rise 3½ feet above tide. The head is greatest at high tides or when nearby marshes are flooded after heavy rains. In the springhouse, at the well, are two cement basins from one of which the water is pumped by wind power to a tank. The water fresh from the well, though perfectly clear, has a slight "sulphur" odor; that from the tank is odorless.

At Cashville, south of Onancock, a number of wells from 80 to 100 feet deep have been sunk. The following record is reported.

Record of well of S. Crockett, on Masitank Creek.

(Authority, Bailey East, driller.)

Material	Thickness (Feet)	Depth (Feet)
Soil, clay and sand	20	20
Mud	25	45
Blue sand	65	110
Blue sand and clam shells	1	111

This well does not flow, though the water rises to within 1 foot of surface; elevation 6 feet.

The elevation of the higher ground about Cashville is 8 to 10 feet. Dug wells 8 to 15 feet deep yield water of varying quality; those near the creek are sometimes salted by high tides. The water from the deep wells is satisfactory. Most of the drilled wells cost $35 to $40, including the 1½-inch pipe.

At Harborton, which has a population of about 450, are perhaps 20 wells that will flow at an elevation of 8 feet above mean high tide. They all tap a bed of coarse sand and gravel at 140 feet. The water is soft and excellent, but at some wells it has a slight "sulphur" odor. A well at Allen & Lenner's fish factory, used for boiler supply at the factory and on fishing steamers, may be the oldest flowing well on the Eastern Shore. The water is said to be satisfactory, the boiler being in good condition after 16 years' use. A field analysis of a sample from this well is given in table 8.

The following record is reported by a local driller. Much the same succession was found in other wells in Harborton.

Record of well of J. W. Adams, Harborton.

(Authority, J. W. Adams, owner.)

Material	Thickness (Feet)	Depth (Feet)
Soil	1	1
Red clay	4	5
White and yellow sand; water at 12 feet	11	16
Blue creek mud	24	40
Gray sand and gravel; water-bearing	11	51
Tough blue clay	74	125
Gray sand, fine at top, coarser below, contains hard streaks and shells; water-bearing	15	140

The deeper wells at Harborton have a 4-foot galvanized iron strainer on the 1½-inch pipe. The casing is usually just long enough, 50 to 55 feet, to cut off the water in the second sand. In a few wells casing is carried to the bottom because of running sand. At a number of the wells are wood or cement tanks into which the water rises and from which pitcher pumps lift it to sinks, etc.

One driller, who furnishes all labor and necessary tools and works on a "water or no pay" basis, charges 45 cents per foot for the first 100 feet and 35 cents for each additional foot. Another driller charges $50 for sinking 140 feet.

A well at Boggs Wharf about one-half mile above Harborton passed through beds of the same general character as those at Harborton, as indicated by the record below.

Record of well of H. Battail, near Boggs.

(Authority, I. B. Clark, driller.)

Material	Thickness (Feet)	Depth (Feet)
Soil	1	1
Red clay	3	4
White sand; poor water	6	10
Blue mud	34	44
Blue sand; very little water	1	45
Blue mud	59	104
Shells in bluish sand rock	8	112
Blue mud, shells and sand rock, four layers of rock in all	38	150

In a moderately coarse greenish-gray sand, not glauconitic, at 150 feet were small bivalve shells. Specimens of these examined by Dr. W. H. Dall were pronounced probably Miocene. The water rises about 4 feet above surface or about 9 feet above mean tide. The quality is good.

Another well a few hundred yards distant showed much the same succession of material.

Record of well of Richard Taylor, at Boggs.

(Authority, I. B. Clark, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Soil	1	1
Red clay	4	5
Yellow sand	5	10
Blue mud	94	104
Bluish gray sand with small shells	1	105

At the mouth of this well is a cement tank. The head is about 8 feet above mean tide.

At Pungoteague village, population about 350, several dug and driven wells sunk to the "first spring," 10 to 18 feet, came under suspicion during an outbreak of typhoid fever, and a number of deeper wells have been put down since. One of these, 210 feet deep, or 190 feet below tide level, is the deepest in use in Accomac County. It cost $120. The driller reported the following succession of beds:

Record of well of S. W. Ames, Pungoteague.

(Authority, I. B. Clark, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Soil	1	1
Yellow sand	15	16
Blue mud, at 40 feet, and 60 feet, slightly sandy, with a little water, at latter point; bluish sand with shells	94	110
Blue mud	3	113
Bluish sand with shells and wood	95	208
Sand; good water	2	210

The well throws considerable sand when pumped hard. The sand is fine, white, well rounded and contains bits of lignitic material. A complete analysis of a sample of water from this well is given in table 8.

There are known to be five water-bearing horizons of varying extent at Pungoteague; the first, at 15 to 25 feet, gives plenty of "medium soft" water containing little iron; the second, at 30 to 40 feet, gives hard, iron-bearing water; the third, at 62 feet, yields water containing little iron; the fourth is at 110 feet; and the fifth at 208 feet gives good water.

Near Craddockville are several flowing wells. The following is a log of one of them.

Record of well of L. J. Nielson, Allen Farm, 2 miles northwest of Craddockville.

(Authority, I. B. Clark, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Blue mud	140	140
Blue sand and shells	33	173

This well was dry when completed, and the water at 170 feet broke in some 48 hours after the driller had stopped work.

Wells along the line of the New York, Philadelphia & Norfolk Railroad.—At the villages south of New Church driven wells reach the "first spring" at 10 to 15 feet; most of them find soft water, but some find decidedly iron-bearing water. The deeper sands frequently yield better supplies.

At Hallwood are two wells over 100 feet deep. The log of one is given below.

Record of well of Jas. A. Hall, at Hallwood.

(Authority, I. B. Clark, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Soil	1	1
Pipe clay, sand and gravel, with water below 10 feet	29	30
Blue mud	80	110
Bluish sand with shells; small yield of good water	40	150
Blue mud	36	186

The yield by a pump was so small that though the water was of good quality, the well was abandoned.

A tank of the New York, Philadelphia & Norfolk Railroad is supplied from a dug well 12 feet deep and from sixteen 2-inch points driven to varying depths. An analysis of the water from the dug well is given in table 7. A partial analysis made by C. B. Dudley for the Pennsylvania System showed 4.91 grains per gallon of total solid residue consisting chiefly of sulphate of lime and magnesia with no carbonates; a slightly corrosive water.

Parksley, one of the largest villages along the railroad, population 500, has no public supply system; nor were drilled wells over 40 to 50 feet deep reported from the village.

At Accomac, the county seat, water is obtained from three sandy beds lying 12, 30, and 50 feet respectively below surface. The water from the first is soft, but that from the second is iron-bearing, and that from the third is soft. The following generalized section is given by a driller who has sunk many wells in the county.

General section at Accomac.

(Authority, I. B. Clark, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Soil	1	1
Red clay	3	4
Yellow and white sand; surface water at 12 feet, better water at 32 feet	28	32
Sticky blue mud	18	50
Coarse bluish sand, gravel, and small shells; good water	1	51

Field assays of samples from three wells are given in table 7.

Near Tasley dug and driven wells average 10 to 15 feet deep and many get water that contains a little iron. Water of better quality is said to be found at 20 feet. The railroad tank is supplied from eighteen 2-inch points driven to varying depths, said to be 22, 35, and 50 feet.

A partial analysis by C. B. Dudley, of water from a well 12 feet deep, showed 4.21 grains of total solid residue per gallon, consisting chiefly of sulphates of lime and magnesia with some chlorides and no carbonates; a slightly corrosive water.

No wells over 55 feet deep had been driven at Onley, 3 miles south of Tasley, and there were only two over 50 feet; most were 10 to 20 feet deep. The following record shows the character of the materials overlying the "second spring."

Record of well of I. W. Rogers at Onley.

(Authority, I. B. Clark, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Soil	1	1
Light gray clay	9	10
Yellow sand, full of water	8	13
Blue mud	35	53
Coarse gravel and pebbles; water-bearing	2	55

About Keller dug wells get water at 8 to 10 feet and are nearly full in wet weather. Driven wells tap sandy beds at 8 to 20 feet. One taps a sand at 60 feet.

Wells on the ocean side south of Chincoteague Bay.—On the ocean side of the county, south of Chincoteague Bay, flowing wells have been drilled along the inlets, the best flows, as on the bay side, being at the base of steep slopes facing open water or marshes. The first attempt it is said, was at the residence of B. T. Gunter, 4 miles southeast of Accomac, in 1899. This well gets water, which rises about 3 feet above the level of mean high tide, from a sand bed at 122 feet below surface. A windmill elevates the water to a tank whence it is piped to the house.

Another flowing well on Custis Neck, ¾-mile southeast of the well just mentioned, is 104 feet deep and flows 100 gallons an hour at an elevation of 1 foot above the surface or about 4 feet above mean high tide; the following record was given by the driller.

Record of well of G. L. Dougherty, one and one-half miles north of Locustville.

(Authority, I. B. Clark, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Soil, sand, clay; surface water	20	20
Blue mud	35	55
Sand; flow of salt water	5	60
Blue mud	40	100
Sand; flow of good water	4	104

At Wachapreague, on the head of Wachapreague inlet, east of Keller, practically all the driven wells get water from the "first spring" at about 10 feet. Along the edge of the marsh at the head of the inlet this water is brackish. A large hotel supplies cistern water for drinking.

Wells on islands in Chesapeake Bay.—The Chesapeake Bay islands included in Accomac County are low, like those on the ocean side; and some are mere patches of salt marsh. The largest of the islands, Tangier, has a population of over 1,200 persons. Most of the dug wells on this island are less than 9 feet deep. The water at some wells is soft and at others, particularly near the shoreline, hard or irony. These shore wells frequently get brackish in droughts or after unusually high tides. Shallow driven wells which yield water of much the same quality as the dug wells are preferred for sanitary reasons.

The only attempt at deep drilling reported is a well driven to 250 feet for J. J. Daly near the center of the island in 1906. A bed of very fine sand 65 feet thick containing salty water which rose to within a few inches of the surface was struck at 141 feet; "rock" at 165 feet, and black mud, "rotten sea-grass and clam shells" at 200 feet and below. No large supply of water was found below 141 feet, and the sand at that depth clogged the pipe.

On Watts Island the deepest well in 1906 was about 70 feet and on Fox Island the deepest was 76 feet. On the latter island a number of wells have been driven by William Ellinger for use at oyster houses. The following carefully kept record shows the character of the beds penetrated:

Record of well on Fox Island.

(Authority, William Ellinger, owner.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Marsh sod	1	1
Marsh mud	6½	7½
Stiff, yellowish-red clay	4½	12
Blue mud	15	27
Conglomerated shells, pebbles and gray limy clay	7	34
Stiff, gray clay	15	49
Hard substance called "coral rock" by driller	1	50
Tough gray clay	13	63
Sand and clay	5	68
Sharp gray or white, fine to coarse quartz sand	6	74
Coarse gravel; water	2	76

The water which rises to within 2 feet of the surface of the marsh, the level fluctuating with the tide, is hard and slightly iron-bearing. The yield with a No. 3 pitcher pump is 10 to 15 gallons per minute. The quality of the water is shown by the field assay in table 7.

The chances of getting plenty of deep water on these bay islands, particularly on Tangier, is so promising that a test by deep drilling should be made. The fine wells on the Great Wicomico River, Virginia, and at Crisfield, Maryland, indicate that abundant flows may be had at about 1,000 feet below sea level in the Upper Cretaceous beds. The water will probably be fully as mineralized as that at Crisfield and may be salty.

Some shallow-well details reported by postmasters are summarized below:

Details of shallow wells in Accomac County.

Post-office	Depth of wells *(Feet)*	Material of water bed	Quality of water
Assawoman	10–25	sand	soft
Atlantic	10–25	clay and sand	hard
Bullbegger	8–25	sand	bad, irony
Fairoaks	8–16	sand	
Graysville	8–12	sand	soft, bad, salty
Horsley	10–40		shallow, irony; deep, good
Leemont	10–18		ditto
Onley	10–28	sand and gravel	soft
Parksley	8–16		hard, irony
Poulson	5–20	sand	
Sinnickson	6–40	clay and sand	poor
Temperanceville	10–25	sand	fair, irony

Conclusions.—By sinking to one or another of the sandy beds above 300 feet it is possible at most places to get supplies of water of satisfactory quality. Owing to their easy pollution dug wells are objectionable. Driven wells can be sunk cheaply and water from those 30 feet or more deep should be free from disease germs.

The outlook for satisfactory water from beds in the Chesapeake deposits 300 feet or more below surface is not especially good. On the mainland in the northern part of the county there is a chance of getting potable water at greater depth, 1,000 to 1,500 feet in the Raritan, but drilling in the hope of reaching better supplies in the Potomac beds, 2,000 feet more below surface, is not advisable. In the southern part of the county deep well prospects are less promising than in the northern.

ALEXANDRIA COUNTY.

General description.—This county, once part of the District of Columbia, is the smallest and most densely populated county in Virginia. The area is 32 square miles. The topography is varied, elevations ranging from sea level to over 400 feet. In places on the heights above 300 feet are remnants of the Lafayette terrace, and several of the Columbia terraces are plainly traceable, particularly the Sunderland at 260 feet near Ballston and Glen Carlyn. The city of Alexandria stands on a somewhat eroded terrace 40 to 50 feet high.

The crystalline rocks, mostly granite and gneiss, outcrop and are quarried along the river above Rosslyn and are exposed in ravines in the western part of the county.

The cobbles, sands, and clays, of the Patuxent formation (Potomac group) outcrop here and there. Northwest of Alexandria the higher (Patapsco) beds rest on gneiss and granite at elevations up to 250 feet above tide, whereas the base of the Patuxent is over 450 feet below tide at the river front in Alexandria.

The Columbia formations contain characteristic cobble beds, sands, and loams. The more highly colored loams of the Lafayette formation are found on the remnants of the high plain between Cherrydale and Falls Church, at Upton Hill, and elsewhere.

UNDERGROUND WATERS

Occurrence and quality.—In Alexandria County water is obtained from the crystalline rocks, from their decayed upper surface, and from Potomac, Lafayette and Columbia sands. Because of this difference of origin the quality varies. Generally the waters are soft; in places they are hard and some deep wells and occasional shallow wells have found water containing considerable iron. In general the water of the deep drilled wells, particularly those at Alexandria, is beyond suspicion, but into many open shallow wells, in places where there is lack of proper curbing, surface impurities are washed at every rain.

Springs.—As a result of an abundant rainfall, and a deeply scored topography, Alexandria County has many springs. They issue from hollows, from hillsides, in ravines, or at the base of terrace scarps. Most of them flow from sandy beds in the Columbia, but a few flow from hard rock. Many of the springs are utilized for household supply or for watering stock, while three are, or have been, of commercial importance. These are the Hume, near St. Asaph, the Erup near Glencarlyn, and the Powhatan south of Upton.

Hume.—This spring or springs, for there are two distinct sources, in the valley of Four Mile Run, is said to have been discovered by troops during the Civil War. It has been improved by a concrete basin, piping, etc. The flows issue from Columbia sands on a terrace. The principal flow, about 10 gallons per minute, is said not to vary with the seasons. The water contains iron and according to some persons, has a slight sulphur odor. It is not sold by the owner, but has been collected and sold by others.

Erup mineral spring.—This spring, about half a mile south of Glencarlyn Station, issues from a high-lying sand and cobble bed. The flow is about 1 gallon per minute. Over the spring is a frame spring house, adjoining this is a frame bottling house with cement-lined iron tanks. The water, which is clear, colorless and odorless, is said to carbonate well. It has been shipped to Washington and sold there, plain or carbonated, for table or medicinal use.

The water has been analyzed several times; the following analysis shows its low mineral content.

Analysis of Erup mineral spring water.

(J. K. Haywood, analyst.)

	Parts per 1,000,000
Silica (SiO_2)	7.9
Sulphuric acid radicle (SO_4)	3.3
Bicarbonate acid radicle (HCO_3)	9.1
Chlorine (Cl)	6.3
Bromine (Br)	none
Iodine (I)	small amount
Iron (Fe)	.1
Manganese (Mn)	none
Calcium (Ca)	2.9
Magnesium (Mg)	1.8
Potassium (K)	1.5
Sodium (Na)	5.7
Lithium (Li)	trace
Oxygen to form oxide of iron (Fe_2O_3) and silicic acid radicle (SiO_2)	1.2
Total	38.8
Total solids	47.8

HYPOTHETICAL COMBINATION

Lithium chloride (LiCl)	trace
Potassium chloride (KCl)	2.9
Sodium chloride (NaCl)	8.1
Potassium iodide (KI)	small amount
Sodium sulphate (Na_2SO_4)	4.6
Magnesium sulphate ($MgSO_4$)	.3
Magnesium bicarbonate ($Mg(HCO_3)_2$)	10.2
Calcium bicarbonate ($Ca(HCO_3)_2$)	.8
Calcium silicate	7.9
Silica (SiO_2)	3.8
Ferric oxide (Fe_2O_3)	.2
	38.8

Powhatan.—This spring is situated about three-eighths of a mile south of Kearney station on the Washington, Alexandria & Great Falls electric railway. It issues from the south side of a ravine, the valley of a small rill that empties into Four Mile Run less than half a mile east of the spring. A dark granite outcrops in the ravine, and the spring is probably of the crevice type, though the point of emergence from the rock is not visible. The coolness of the water indicates a source deeper than that of many hillside springs. The flow is about 10 gallons per minute; the quality clear, tasteless, and odorless. The spring basin is protected by a masonry chamber; there are no possible sources of pollution near, and the sanitary conditions are good.

There is a masonry bottling house at the spring from which water has been shipped to Washington. The following analysis was made by the Bureau of Chemistry.[a]

Analysis of Powhatan spring water.

(J. K. Haywood and B. H. Smith, analysts.)

	Parts per 1,000,000
Silica (SiO_2)	12.0
Sulphuric acid radicle (SO_4)	1.2
Bicarbonate acid radicle (HCO_3)	12.0
Nitric acid radicle (NO_3)	1.55
Nitrous acid radicle (NO_2)	.016
Phosphoric acid radicle (PO_4)	none
Metaboric acid radicle (BO_2)	none
Arsenic acid radicle (AsO_4)	none
Chlorine (Cl)	3.8
Bromine (Br)	none
Iodine (I)	trace
Iron and aluminum (Fe + Al)	.2
Manganese (Mn)	none
Calcium (Ca)	1.6
Magnesium (Mg)	1.2
Potassium (K)	1.2
Sodium (Na)	3.7
Lithium (Li)	none
Ammonia (NH_4)	.069
Oxygen to form Fe_2O_3	.10
Total	38.435
Free ammonia	.065
Albuminoid ammonia	none
Nitrogen as nitrates	.350
Nitrogen as nitrites	.005
Oxygen required	.45

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[a] Haywood, J. K., and Smith, B. H., Mineral Waters of United States, Bull. 91, Bureau of Chemistry, 1905, p. 43.

Analysis of Powhatan spring water—(Continued).

HYPOTHETICAL COMBINATION

	Parts per 1,000,000
Ammonium chloride (NH_4Cl)	0.207
Potassium chloride (KCl)	2.3
Sodium chloride ($NaCl$)	4.3
Potassium iodide (KI)	faint trace
Sodium sulphate (Na_2SO_4)	1.8
Sodium nitrate ($NaNO_3$)	2.12
Sodium nitrite ($NaNO_2$)	.024
Sodium bicarbonate ($NaHCO_3$)	2.9
Magnesium bicarbonate ($Mg(HCO_3)_2$)	6.0
Calcium bicarbonate ($CaCO_3$)	6.5
Ferric oxide and alumina ($Fe_2O_3 + Al_2O_3$)	.3
Silica (SiO_2)	12.0
Total	38.451

Public supplies.—The city of Alexandria, population about 17,000, is supplied with water taken from a creek, Cameron Run, about 3 miles above the city. The military post of Fort Myer is supplied with water from Potomac River.

LOCAL SUPPLIES

Alexandria.—There are a number of dug wells owned by the city and many privately owned ones. These wells 20 to 40 feet deep get water from sandy and gravelly Columbia beds. In 1906 some were liable to pollution from leaky sewers or cesspools.

Deep wells have been drilled for the Robert Portner Brewing Co., the Mutual Ice Co., the Alexandria Fertilizer and Chemical Co., and the Belle Pré Bottle Co. At the Portner brewery, on a slope 40 feet above tide, are four 8-inch wells down about 400 feet and one 6-inch well down 61 feet, the greatest depth of well reported being 430 feet. The wells are pumped by air lift. The water is low in lime but alkaline enough to make an admirable boiler water. It is used for brewing, for ice-making, and for washing as well as for steam production. A number of families in the vicinity of the brewery get the water for drinking. The water from the 61-foot well contains considerable iron and is used only for cooling condenser coils and washing the outside of kegs and barrels. Analyses of water from two of the deep wells, made in 1903, are given below. Well No. 1 had been in use 20 years; well No. 2 had just been completed.

Analyses of water from wells of Robert Portner Brewing Co., Alexandria.

(First Scientific Station for the Art of Brewing, analyst.)

	Parts per 1,000,000	
	No. 1	No. 2
Total solids	118.0	170.0
Organic and volatile matter	12.0	14.0
Iron and aluminum oxides ($Fe_2O_3 + Al_2O_3$)	trace	4.0
Calcium (Ca)	.....	.....
Magnesium (Mg)	.....	.....
Chlorine (Cl)	24.8	19.5
Alkaline carbonates	114.4	109.0
Sulphuric acid (SO_3)	11.6	12.0
Nitric acid	0.0	0.0
Nitrous acid	0.0	0.0
Free ammonia	trace	trace
Albumenoid ammonia	small trace	small trace
Total hardness	15.6	20.0

A later analysis made by the United States Geological Survey is given in table 11.

The 8-inch well of the Peoples Ice Company is on the river front. It is 401 feet deep and cased to the bottom. The water rises about to tide level, 12 feet below the top of the well. Pumping 90 gallons a minute lowers the water to 60 feet from the top. The water, like that from the Portner wells, is colorless, odorless, and tasteless. It is used for making ice and has been bottled and sold for table use under the name of Mico water. An analysis furnished by the company but recalculated to express results in the form adopted by the U. S. Geological Survey shows the following mineral content:

Analysis of Mico Water.

(J. D. Hird, analyst.)

	Parts per 1,000,000
Total solids	176.
Organic matter	0.
Silicia (SiO_2)	21.
Calcium (Ca)	trace
Magnesium (Mg)	1.4
Sodium (Na)	49.
Bicarbonate radicle (HCO_3)	39.
Sulphate radicle (SO_4)	36.
Chlorine (Cl)	32.

A well sunk in 1906 at the plant of the Alexandria Fertilizer and Chemical Co., on the water front a quarter of a mile north of the well of the Peoples Ice Co., illustrates the variability of the Patuxent sands as water bearers, the poor quality of the water in some of the sands and the difficulties that beset a driller unaccustomed to working in the Potomac sands and sandy clays.

A standard cable rig was used and rapid progress made for the first 250 feet. Below 300 feet progress was slower and the 8-inch casing after a series of accidents finally collapsed at 397 feet. An attempt to go deeper with 6-inch casing resulted in reaching a total depth of 445 feet, beyond which it was impossible to drive the casing, though this was heavy pipe, without its collapsing. Little water was found and none that would flow at surface, 10 feet above tide. Dynamiting at 350 feet gave a small yield which rose to 80 feet of surface. Dynamiting at 225 feet gave water which rose nearly to tide level. The yield is 60 gallons per minute, by air lift, the end of the air pipe being 215 feet down the well.

The water from the sand and gravel at 225 feet has not improved in quality under heavy pumping. It is clear and colorless when fresh from the well but becomes turbid and deposits iron on standing. It has an acid reaction and is not suitable for boiler use. A partial analysis showed solids amounting to 1,265 parts per million, chiefly sulphates.

A 6-inch well drilled for the Belle Pré Bottle Co., half a mile northwest of the brewery, is 185 feet deep; the water, from a sand bed in the Patuxent formation, rises to 25 feet of surface, elevation 40 feet; pumping 65 gallons lowers it 10 feet. It is used for boiler supply, though it forms a tough hard scale, and for other purposes at the company's glass works. The analysis in table 11 was made by the U. S. Geological Survey in 1910. The difference between this water and that from the deeper wells is marked.

Other localities.—On the heights west of Alexandria most residences get water from dug wells; a few have drilled wells. The supplies come from Columbia or Potomac sands and cobble beds. Depths to water and quality of supplies vary. Thus a drilled well about 125 feet deep on the southeast slope of Shooter Hill obtains iron-bearing water that rises to 60 feet of surface from a Patuxent sand bed; whereas about 100 yards east, and a little higher up the hill, a well only 20 feet deep yields an abundant supply of soft clear water. At most wells the water is soft.

The irregular occurrence of water in crystalline rocks in the western part of the county is shown by the following records furnished by N. H. Darton. The second well is 150 feet east of the first.

Record of well of G. N. Saegmuller, Chain Bridge.

(Authority, W. C. Miller, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Micaceous red clay	60	60
Soft micaceous rock	10	70
Gneiss	485	555

A little water, about 2 gallons per minute, was found at 80 feet and no water below.

Record of well of G. N. Saegmuller, Chain Bridge road.

(Authority, W. C. Miller, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Micaceous red clay	60	60
Soft micaceous rock	11	71
Gneiss	10	81

The yield of this well was 8 gallons per minute.

The record of another well that obtained water from granite is given below.

Record of well of A. M. Lathrop, Upton Hill, near Fostoria.

(Authority, W. C. Miller, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Micaceous red clay	60	60
Soft micaceous rock; small supply of water at 60 feet	34	94
Soft gneiss	80	172

According to the driller, this well, when completed, yielded 15 gallons per minute of excellent water.

About Addison and Arlington Junction are many dug wells and a few drilled wells. The dug wells are 15 to 25 feet deep. The drilled wells vary greatly in depth. One at the power house of the Washington, Alexandria & Mt. Vernon railway, near Luna Park, yields a small flow of good water from a sand bed reported to be but 36 feet below surface. The comparatively high head of the flow, about 20 feet, is explainable by the water bed receiving supplies from the hill on the Luna Park grounds, and thus having an initial head of possibly 100 feet. At the plants of the Standard Brick Co., and of the New Washington Brick Co.

near Addison are wells 140 feet and 131 feet deep respectively, tapping Patuxent beds. The water is used for boiler supply and for drinking. An analysis of the water from one of the wells appears in table 11.

There are no deep drilled wells at Rosslyn. Most dug wells obtain soft water from Columbia or Potomac sands and cobble beds. Depths range from 15 to 40 feet.

On the terrace near Ballston, Clarendon, Veitch and Kearney, dug wells about 20 feet deep are practically the sole source of supply. The water lies chiefly in Columbia sands or cobble beds and is soft at most wells; a few wells yield hard water and a few water that is irony.

About Glen Carlyn dug wells are 20 to 35 feet deep. The water, in Columbia cobble beds, is soft as a rule.

Falls Church lies chiefly in Fairfax County and its water supply is described under that county.

Conclusions.—The underground water resources of Alexandria County are considerable and can meet far greater demands than those at present made. At Alexandria and along the river front northward, it will probably pay any concern using large amounts of water to have a competent driller make a test to bed rock. Exact prediction of depth to good boiler water at a particular point is impossible. It is probable that such water will be found within 100 feet of bed rock, that a deep well will penetrate a number of water-bearing sands, and that wells a short distance apart will get water of different quality from about the same depth.

Deep drilling on the higher terraces to develop water in the crystalline rocks is a more uncertain venture. It will often be justified by sanitary considerations.

CAROLINE COUNTY.

General description.—Caroline County, formed in 1727 from portions of Essex, King and Queen, and King William counties, lies in the western part of the Coastal Plain between Rappahannock and Mattaponi rivers and extends into the Piedmont region.

The topography is of the western shore type. On the highest terraces are patches of swamp in which head sluggish brooks that meander to the edge of the terrace, then descend rapidly through sharply cut valleys to the lowest terrace. Elevations range up to 250 feet. The Lafayette terrace caps divides in the western end and the Sunderland terrace occurs on the divides in the eastern end of the county. Lower terraces make the second and first bottoms of Rappahannock and Mattaponi rivers.

The oldest rocks exposed at the surface within the Coastal Plain part of the county are the Triassic sandstones and shales in the valley of the South Anna River. The sands, gravels, sandstones, and clays of the Potomac, the greensands of the Pamunkey, and the clays and sands of the Chesapeake all outcrop.

UNDERGROUND WATERS.

Because of the topography and because of the variability in composition of the surficial deposits, the depth to the water table and the character of the ground water vary greatly. On projecting headlands of the Lafayette or Sunderland terraces dug wells may have to go 60 feet to get water, while on level interstream areas of the same formation wells may find sufficient supplies within 12 feet of surface and be full to the top after prolonged rains. On the lower terraces the differences in depth to water are less but the wells are more apt to go dry in drought. The sands of the high terraces yield water that is mostly soft but in places it is hard. Waters in the lower terraces are more apt to be hard or iron-bearing. Wells sunk through the terrace formations or through valley wash into the Chesapeake deposits obtain water that may be soft; if the water comes from a bed of shell marl it may be decidedly hard. Supplies may be scanty, though the wells penetrate the clayey sands for 50 feet. The Potomac and Pamunkey sands, tapped by drilled wells along Rappahannock River, yield flows of soft water of good quality that has a faint "sulphur" odor.

Springs.—Because of the topography Caroline County contains many springs of the Coastal Plain type. They are comparatively little used for household supply and none is of commercial importance. One near Guineys has a local reputation for yielding water of theraputic value.

Wells.—Dug wells, most of them having a wood curbing at the bottom, are the chief source of supply. There are comparatively few driven wells in the county and perhaps 10 drilled wells along Rappahannock River.

The usual price for digging a well is $5. This does not include extra labor needed and lumber used for curbing.

LOCAL SUPPLIES

Bowling Green.—Practically all the water used in this village, the county seat, is obtained from dug wells 25 to 35 feet deep which give enough water for household use, but few withstand continued heavy pumping after prolonged dry weather. Some of the wells are poorly located.

According to R. P. Vincent, there are about 60 dug wells in the village. He gives the following as an average section of the materials penetrated.

Generalized section at Bowling Green.

(Authority, R. P. Vincent.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Red loam	7	7
Red loam and pebbles	7	14
Yellow sandy clay, with seeps of water	12	26
Gray sand, main supply of water	6	31

The supplies show unexpected variations in quality, due either to the chaotic assortment of materials in the basal beds of the Sunderland formation or to some wells striking shell beds in the Chesapeake. The water from the public well in front of the old courthouse is soft and contains little iron, while almost directly across the street, the well of R. P. Vincent gives water that is hard and contains iron. The village has a reputation for healthfulness, so the supplies obtained from the dug wells are presumably satisfactory from a sanitary standpoint.

Results of field assays of the water from neighboring wells appear in table 7.

Other localities.—At Milford on Mattaponi River the dug wells average 20 feet deep, and get water from sandy and gravelly Columbia beds. The water in a number of the wells is decidedly irony.

The dug wells at Port Royal go deeper than at Milford; some pass through the Columbia sands and get hard water in the Pamunkey greensands at 20 to 25 feet. The artesian wells at or near Port Royal tap coarse greensands and gravels at the bottom of the Aquia formation. The water is beautifully limpid, has a faint "sulphur" odor and is distinctly alkaline.[a] One of these wells, owned by the corporation of Port Royal, is on the river edge just below the steamboat landing. It is 272 feet deep, 1½ inches in diameter, and flows 2 gallons per minute, the flow varying slightly according to the stage of the tide. An attempt to get a supply on the terrace, elevation 20 feet, by a ram, proved disappointing and was abandoned. The other wells at and below Port Royal get water from the Aquia. A few wells farther up stream get water from "quicksand" in the Potomac. One of these wells at Hayfield farm near Horseneck is 169 feet deep and just flows at an elevation of 25 feet above tide. The driller reported the following log:

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[a] For field assay of water, see table 9.

Record of well of A. B. Lewis, 9 miles southeast of Fredericksburg.

(Authority, Geo. Heflin, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Red clay and gravel	20	20
Blue marl; water at bottom; this water cased off	80	100
Quicksand, "green with white spots"; main flow at 167 feet	67	167

The following summarized statement shows the variations in depth to water and quality of supplies at several localities dependent on dug wells. The data are from reports by postmasters and others.

Details of dug wells in Caroline County.

Post-office	Depth of wells *(Feet)*	Water bed	Quality of principal supply
Brandywine	25 to 45	....	Hard, soft
Central point	40	....	....
Chilesburg	16 to 24	Clay and gravel	Soft
Delos	10 to 20	Sand	Soft
Edgar	25 to 40	Iron crusts	Shallow, soft; deep, hard
Ezra	30 to 50	Gravel	Soft
Golansville	16 to 50	Gravel	Soft
Guineys	15 to 25	Sand, blue clay	Fair, irony
Milford	10 to 60	Sand, gravel	Soft, irony
New London	30 to 35	....	....
Penola	10 to 75	....	....
Return	40	....	....
Rappahannock Academy	20 to 45	....	....
Woodford	12 to 30	Gravel	Soft

Conclusions.—Except at a few villages present supplies of water are equal to local demands. Water that is above suspicion of pollution can be had from the Pamunkey and the Potomac sands by properly drilled wells, but flows are not to be expected at over 25 feet above sea level.

At Bowling Green excellent water for domestic use can be had from the Pamunkey at a probable depth of 400 feet. As this water will not rise within 100 feet of surface, the well would have to be pumped, hence should be of sufficient diameter. At Milford a flow at the surface from either Pamunkey or Potomac sands is doubtful. Enough water to keep fire tanks full and supply several buildings can be had on the terrace at Port Royal by attaching a hydraulic ram to a carefully drilled and cased well of larger diameter than those now in use. On the Mattaponi no artesian wells have been sunk, but flows may be struck at 300 feet below tide level at the east line of the county. In general flows are not to be expected and supplies that will rise 20 feet above river level are unlikely. There is a good prospect for flows at less elevation east of Penola. The Newark rocks on the North Anna River are uncertain water-bearers, as shown by the deep well at Doswell.

CHARLES CITY COUNTY.

General description.—Charles City County, one of the original shires of the colony of Virginia, was formed in 1634. It extends along the north side of James River to the eastern end of the peninsula between James and Chickahominy rivers.

Away from the rivers the western end of the county has a gently rolling surface, cut here and there by some tributary of the James or the Chickahominy. An altitude of 200 feet is reported just south of Roxbury. This high point is a remnant of the Lafayette terrace, and other remnants of the Lafayette terrace may be seen northeast of Malvern Hill. The lower terraces are plainly evident in the east end of the county. On the James the development of the Wicomico terrace gives the topography a peculiar, drowned look; red hills, remnants of the Sunderland terrace, project above the buff loams and clays of the Wicomico plain. This is particularly noticeable on the road from Charles City to Richmond, between the Willcox Wharf road and Herring Creek. Along the Chickahominy which, above Providence Forge, flows for 40 miles through a narrow swamp, a low terrace is well developed.

The Columbia or the Lafayette overlies the clays, sands, and marls of the Chesapeake, on the higher land in the eastern part of the county. The Chesapeake is probably not more than 120 feet thick, thinning toward the west. Along James River, from the west line of the county to Herring Creek, the greensands of the Pamunkey lie just below the Columbia and are exposed in bluffs. The Chickahominy has not cut its way down to the Pamunkey, though at Roxbury the cover of Chesapeake is less than 50 feet thick.

UNDERGROUND WATERS

Occurrence and character.—Supplies of underground water sufficient for the needs of farm houses can be obtained on the terraces from wells sunk in the Lafayette or the several Columbia formations. The depth to the water table varies according to topography, depth of the surficial deposits, freedom of ground water movement, etc. Some anomalous conditions result. For instance, near Shirley some wells on projecting headlands of a Sunderland plain get water at 15 feet in loam, while on the Wicomico terrace 50 feet below and not over 300 yards distant, wells go 30 feet to water. The quality of the supplies from the Sunderland and Wicomico formations varies, but is generally soft. On the stretches of a low-lying terrace near James River, excellent water can be had by driven points 20 to 30 feet deep. Water from shallow wells in the Chickahominy valley has a bad reputation, being thought to cause malaria, and intestinal diseases. Part of this ill-repute is no doubt due to the use of dug wells.

Springs.—Charles City County has its share of springs, most of which are of the ordinary Coastal Plain type, flowing from terrace gravels above Chesapeake or Pamunkey beds of sandy clay. The flows are small, probably averaging less than 5 gallons per minute, but the waters are soft. No spring is the site of a health or pleasure resort, and from none is water shipped in commercial quantities. A few that are noticeable for one reason or another are those of John Ruffin, 6 miles west of Charles City; E. A. Saunders at Buckland Farm in the same section; and R. W. Swift 2 miles southeast of Elko. The last, situated in a hollow by a run that empties into Chickahominy River, has a fine flow of 20 to 25 gallons per minute from clayey and sandy beds near the bottom of the Wicomico formation. Other good springs are found along the same run. The water from Mr. Swift's spring is clear and sparkling, and is used for all domestic purposes. A field assay is given in table 6.

Wells.—The dug well, cased with wood, is the chief source of underground water supply. In places on the lower terraces along James River driven wells are used. There are few deep drilled wells, though water-bearing beds in the Pamunkey or Potomac underlie the entire county.

LOCAL SUPPLIES

Of the deep wells reported, one 280 feet deep, near the Chesapeake & Ohio railroad station at Roxbury, on the edge of the cypress swamp along Chickahominy River, was drilled for T. L. Watson to furnish drinking water of better quality than could be procured by dug wells, and to supply a mill boiler. The water rises to within 2 feet of surface, or about 40 feet above mean high tide in James River. According to unverified reports a small flow was struck at 70 feet, but was cased off. The main flow is from a Potomac gravel bed. The water, pumped by a windmill, is clear and soft with a very slight sulphur taste. It works nicely in a boiler, and is called an excellent table water.

One of the finest wells in the section along James River was sunk for W. M. Ramsey, on the famous estate known as Westover. The well, which is 10 inches in diameter and 139 feet deep, found water in a bed of gravel and black sand (basal Pamunkey) at 132 feet; this water rises to 10 feet of surface, or 10 feet above mean high tide. Pumping 70 gallons per minute lowers the water 8 feet. A 4 horse-power gas engine belted to a horizontal pump, forces the water to a tank whence it is piped to the house, stables, and other buildings. The water is clear, tasteless, and odorless.

At Bucklands stock farm, near Bucklands Landing on James River, are 6 flowing wells ranging in depth from 168 to 184 feet that reach Pamunkey sands. The flows are free, ranging from 6 gallons through a 2-inch pipe, at the well on the highest ground, elevation 24 feet, to 80 gallons per minute at a well by the river. The reported head of the flows is about 32 feet above river level. (See table 5.)

Near Charles City dug wells are found 25 to 40 feet deep, averaging 30 feet, and ordinarily contain 4 or 5 feet of water. In most wells the water is called hard.

The following section in a road cut at Courthouse Creek shows the general character of the Columbia and Chesapeake beds reached by dug wells.

Section at Courthouse Creek, Charles City.

Material	Thickness *(Feet)*	Depth *(Feet)*
Gray, buff, and red loam and clay	10	10
Discontinuous band of cobbles	1	10
Gray sand	3	14
Iron crusts and sand	2	16
Coarse yellow and orange sand	10	26

Near Binn's Hall dug wells are 12 to 60 feet deep, most being from 12 to 25 feet; the water in the shallow wells is soft, in the deep hard. Near Oldfield the wells average around 30 feet and yield soft water; near Sturgeon depths range from 20 to 70 feet, averaging 50 feet. The water is soft. On the terrace back of Wilcox Wharf wells are 30 to 45 feet deep. One on the bluff, belonging to T. W. Hubbard, went 12 feet through red and buff clay and 31 feet through sand, gravel, and iron crusts, with pebbles near the bottom. The water is soft and excellent for domestic use. (See analysis, table 8.)

At Eppes Island on James River, driven wells get good water from the Talbot formation at 15 feet. At and near Shirley are a considerable number of driven wells. They are from 27 to 35 feet deep. H. S. Saunders gives the following average record for wells at Upper Shirley.

Generalized section at Upper Shirley.

(Authority, H. S. Saunders.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Soil	3	3
Tough gray clay	10	13
Reddish sandy clay	15	28
Cobble bed	4	32
Coarse gravel, water-bearing	1	33

A field assay of a sample of water from a 30-foot well is given in table 7.

This well, driven some 15 years ago, is situated in a slight hollow of a terrace about 25 feet high. To guard against surface water working down along the pipe a hole 4 feet in diameter and 1 foot deep was dug about the pipe and filled with concrete. A deep well drilled for Mr. Saunders struck bed rock at 350 feet. It did not get a flow.

Near Malvern Hill post-office wells are from 20 to 70 feet deep; some of the deeper ones go down into "marsh-mud," probably fine dark clays of the Pamunkey, and obtain little water. A well at the post-office, said to be 50 feet deep, though nearly full in wet weather, is said to go dry in droughts; it evidently gets little water except what comes in near the surface. In the neighborhood are several 8-inch wells bored by an earth auger and cased with 12-inch tile. One of these owned by J. M. Gill, 70 feet deep, cost $15 to bore. This well is said to be sunk through "marsh-mud" below the surface sands and loam. The depth from which the main supply of water comes in wet weather is uncertain. The character of the water in 1906 is indicated by the field assay in table 8.

Data regarding dug wells at a number of places in the county are presented in the accompanying table.

Details of dug wells in Charles City County.

Post-office	Depth of well *(Feet)*	Water bed	Quality of principal supply
Binn's Hall	12–60	Sand and marl	Hard and soft
Holdcroft	13–30	Sand	....
Oldfield	35	Sand	....
Lent	30–75	Marl	Hard
Lame	30	Sand	Soft
Sturgeon Point	15–60	Sand and clay	Soft

Conclusions.—Good water can be had by dug, driven, and drilled wells in Charles City County. On the low ground along Chickahominy River where the shallow water is regarded with suspicion, plentiful supplies can be had from Pamunkey sands 150 to 300 feet below sea level; along the tidal portion of the river, south of Boulevard, basal sands of the Chesapeake group 100 to 150 feet below sea level, may yield small flows at elevations less than 10 feet. Along James River in the eastern half of the county good flows can be had from the Pamunkey, but heads 25 feet above river level should not be expected.

CHESTERFIELD COUNTY.

General description.—Chesterfield County, formed from Henrico County in 1748, is bounded on the north and east by James River and on the south and west by Appomattox River, but only that part of the county east of a line from Richmond to Petersburg lies within the geologic province considered in this report. In this part of the county elevations range up to 210 feet. James River and Appomattox River have cut gorges nearly 200 feet deep in what was a gently rolling plain, and tributary creeks have V-shaped valleys. Near the rivers the Columbia terraces have been largely removed, but remnants of the Sunderland and Wicomico terraces are traceable back of Manchester and along the road from Manchester to Petersburg. The Talbot terrace is nowhere conspicuous.

A gray granite, in places gneissoid, outcrops about Manchester and causes rapids in James River. It also outcrops near Ettricks on Appomattox River. The sand, sandstone, and cobble beds of the Patuxent formation are exposed in places along James River and are conspicuous on the north bank of Appomattox River. The dark green glauconitic sands of the Nanjemoy formation outcrop at Powhatan and elsewhere on Appomattox River. The sands and diatomaceous clays of the Calvert overlap the Nanjemoy, resting on that formation, the Patuxent, or the granite. The yellow, buff, and reddish loams of the Lafayette and Sunderland formations mantle the divides.

UNDERGROUND WATERS

Occurrence and character.—Ground water, stored in the coarser beds of the Lafayette and of the various Columbia formations, is the chief source of supply. Depths to the water table show the usual variations characteristic of the western edge of the Coastal Plain and range from 5 to 50 feet. The water as a rule contains little mineral matter in solution and is clear and soft.

Springs.—Chesterfield County contains many springs. As fastidious people in Richmond desired water of better appearance and greater purity than the supplies that were, until the installation of purification plants, furnished by the city waterworks, some of the owners of conveniently situated springs have sold large quantities locally, and have extended business to points outside the State. Some of the important springs are outside the Coastal Plain area, and flow from crevices in crystalline rocks; others, just within it, issue from gravelly beds in the surficial loams of the Lafayette or the Sunderland terrace. All the springs of note are mentioned here. Five of these springs have been advertised more or less extensively; the waters from several others have been sold or have been used in the manufacture of ginger ale and other sweetened beverages.

Perhaps the longest known of the springs is the Fonticello, situated in Swansboro, a suburb of Manchester, on a tract of land that is said to have been an Indian camp ground during the time of Powhatan. The spring issues from a crevice in the granite-gneiss exposed by a slight hollow in the red cobbly Lafayette loam that mantles the high ground west of Manchester for an undetermined distance. It flows from the cleft in the rock at the rate (estimated) of 18 to 19 gallons per minute and, according to the proprietor, shows no seasonal changes in flow. The water is pumped from a cement basin in the stone spring house to the bottling room. The overflow from the basin supplies a small pond. The grounds about the spring are laid out as a park. Care has been taken to exclude surface water by digging a blind ditch around three sides of the spring and laying tile drains. The source of the flow is uncertain, but the location of the spring, in a hollow on high ground, the temperature of the flow, 61° F. in October, 1906, the manner of emergence, and the character of the water indicate that the source is not deep. The water probably accumulates in the gravels of the Lafayette on the higher ground to the west and flows by connecting joints in the underlying granite to the outlet.

Fonticello Lithia water, as the output of the spring is called, is shipped in bottles and carboys. It is sold for table use and as a light bicarbonated alkaline water for disorders of the liver and kidneys.

The following analysis is recomputed from that given in circulars sent out by the proprietor.

Analysis of Fonticello Lithia water.

(Henry Froehling, analyst.)

	Parts per 1.000.000
Total solids	46.
Silica (SiO_2)	14.
Iron (Fe)	1.6
Aluminum (Al)	0.07
Calcium (Ca)	2.0
Magnesium (Mg)	0.61
Sodium (Na)	3.5
Potassium (K)	1.5
Manganese (Mn)	trace
Lithium (Li)	0.08
Arsenic (As)	trace
Bromine (Br)	trace
Bicarbonate radicle (HCO_3)	13.
Sulphate radicle (SO_4)	2.5
Phosphate radicle (PO_4)	0.04
Chlorine (Cl)	5.4
Free carbon dioxide (c. c. per liter)	30.

Not far from the Fonticello, in Manchester, on a hillside pasture lot in the shallow valley of a small run, is another spring flowing from a cleft in granite. This spring, known as the Bellfont, has been less advertised than the Fonticello, and the water is sold chiefly for table purposes in Richmond.

The water is clear, tasteless, and odorless. There were, in 1906, no buildings on the slope above the spring for 200 yards or more, and the sanitary surroundings were good. The flow, estimated at about 20 gallons per minute, is said not to vary during the year. The only improvements at the spring at the time it was seen were a cement basin and a small frame springhouse. In essential characteristics of origin and emergence, this spring resembles the Fonticello, and the water has much the same composition. The following analysis was furnished by the former proprietor, Clarence Vaden, of Manchester.

Analysis of Bellfont Lithia water.

(W. H. Taylor, analyst.)

	Parts per 1,000,000
Total solids	44.
Silica (SiO_2)	14.
Iron (Fe)	1.0
Calcium (Ca)	1.9
Magnesium (Mg)	0.4
Sodium (Na)	3.8
Potassium (K)	2.9
Lithium (Li)	0.03
Bicarbonate radicle (HCO_3)	5.3
Sulphate radicle (SO_4)	10.
Chlorine (Cl)	5.8

About 1 mile southeast of Swansboro post-office, in a tract of land partly wooded, partly open, is a group of springs from which water has been sold from time to time. In 1905 the title passed to people who made extensive improvements with the apparent intent of having more ornate surroundings there than at any spring near Richmond. The spring-house, open at the sides, has a concrete floor, the basin is walled with slabs of white marble, and a niche of similar slabs surrounded by an ornamental iron screen is built above it. These springs, known as the Holly Lithia springs, are situated in a slight hollow of the almost level surface of the plain. The chief spring is a "boiling spring," the water rising from a bed of coarse sand, gravel, and cobbles beneath a few feet of surface soil and loam. Dug wells in the vicinity strike granite at from 5 to 30 feet below surface. The water is clear, tasteless, and odorless, and contains free carbon dioxide, bubbles of which can be seen rising in the basin. When the spring was inspected there were no dwellings nor other buildings so situated that contamination of the spring water from them was possible. The source of the water is evidently shallow, as indicated by the temperature, 62½° F., in October, 1906. The present volume of flow was determined, it is said, by the improvements made; a flow sufficient to fill a 4-inch pipe was obtainable by lowering the level of the water in the spring basin 2 feet.

The output has been sold for table use almost exclusively. The following analysis, furnished by the manager, J. P. Carson, of Richmond, shows a lower mineral content than the Fonticello and Bellfont springs, but the same type of mineralization. An analysis made thirteen years before, by Chas. H. Chalkley, agrees closely with the later analysis.

Analysis of Holly Lithia water.

(Froehling & Robertson, analysts.)

	Parts per 1,000,000
Total solids	35.4
Silica (SiO_2)	11.
Iron (Fe)	0.35
Aluminum (Al)	0.8
Calcium (Ca)	1.4
Magnesium (Mg)	0.35
Barium (Ba)	0.008
Sodium (Na)	4.6
Potassium (K)	1.
Lithium (Li)	0.033
Bicarbonate radicle (HCO_3)	4.8
Sulphate radicle (SO_4)	4.3
Phosphate radicle (PO_4)	0.029
Nitrate radicle (NO_3)	2.7
Iodine (I)	trace
Chlorine (Ca)	4.4

Three miles south of Manchester, at Swineford Station, on the Atlantic Coast Line Railroad, is the spring formerly known as Swineford's spring, and now called the Lion Lithia spring. It is owned by the Virginia Lithia Springs Co. It is a boiling spring, the water rising through coarse gravels in a terrace slope west of the railroad. The flow, which is said not to vary with the seasons, is about 10 gallons per minute. Its temperature when measured, October, 2, 1906, was 63° F. The owners do not claim for the water, which is clear and bright, without color, taste, or smell, any therapeutic value, but simply state that it is a good table water. Part of the output is sold still in carboys, part is carbonated and sold in bottles, and part is used for making ginger ale. The following analysis is recomputed from one furnished by the company.

Analysis of Lion Lithia water.

(Froehling & Robertson, analysts.)

	Parts per 1,000,000
Total solids	28.1
Silica (SiO_2)	10.
Iron (Fe)	0.11
Manganese (Mn)	0.022
Aluminum (Al)	0.18
Calcium (Ca)	1.0
Magnesium (Mg)	0.40
Lithium (Li)	.011
Sodium (Na)	3.
Potassium (K)	1.2
Bicarbonate radicle (HCO_3)	3.9
Phosphate radicle (PO_4)	0.035
Sulphate radicle (SO_4)	4.1
Arsenate radicle (AsO_4)	0.039
Chlorine (Cl)	3.6
Iodine (I)	trace
Bromine (Br)	trace
Free carbon dioxide, 54 c. c. per liter.	

When the writer saw the spring there were no buildings above it for a considerable distance, and the chances of pollution were remote. The spring house had a tile floor, concrete walls, and an open roof. From the basin the water flowed to the bottling house, a two-story frame building 400 feet distant, which contained carbonators, automatic washing machines, etc.

Four miles west of Manchester, in a shallow ravine, is a spring with a flow of 25 to 30 gallons per minute, known as the Beaufont. It issues from a cleft in granite, and is covered by a frame spring house with cement floor. The water, which is clear and without taste or odor, had, when the spring was visited on October 2, 1906, a temperature of 57° F. It flowed through a tile pipe line to a bottling house by the roadside, 100 yards or more from the spring. Most of the output was said to be used in making ginger ale. The following analysis, furnished by the proprietor, has been recomputed to express results in standard form.

Analysis of Beaufont Lithia water.

(Henry Froehling, analyst.)

	Parts per 1,000,000
Total solids	63.
Silica (SiO_2)	16.
Iron (Fe)	0.25
Aluminum (Al)	8.4
Calcium (Ca)	1.4
Magnesium (Mg)	1.0
Sodium (Na)	4.0
Potassium (K)	2.1
Manganese (Mn)	trace
Lithium (Li)	0.07
Arsenic (As)	trace
Bicarbonate radicle (HCO_3)	15.
Sulphate radicle (SO_4)	1.3
Phosphate radicle (PO_4)	0.04
Chlorine (Cl)	5.2
Iodine (I)	0.06
Bromine (Br)	trace
Free carbon dioxide (CO_2)	37 c. c. per liter

In 1906 the land about the spring was largely wood-covered; there were no dwellings near, and pollution was improbable.

Situated at Buckhead Springs Station, on the Seaboard Air Line Railroad, about ½ mile east of Centralia, at the head of a run that empties into Proctor Creek, are the Buckhead springs, a group of three, with a total flow of about 2½ gallons per minute. The water, which comes from sandy beds in the Sunderland formation, is bright and sparkling, without taste or odor. The flow is said not to vary in volume or temperature throughout the year. The proprietor has taken strict precautions to insure the sanitary excellence of the spring surroundings. The residences and farm buildings on a small area of level ground, a remnant of a high Columbia terrace, are about 300 yards from the springs. Concrete walls and tile drains about the springs prevent the entrance of surface water. The water flows from the concrete basin at the spring-house through an enamel pipe to an enamel filling basin in the bottling house, a frame building, 60 by 20 feet, near the railroad track, where it is at once securely sealed. The output has a wide sale as a table and as a medicinal water. It contains free carbon dioxide, hence is light and pleasant. The following analysis, recomputed from one furnished by the proprietor, Thos. S. Wheelwright, of Centralia, shows a low mineral content.

Analysis of Buckhead Chloride Lithia water.

(Froehling & Robertson, analysts.)

	Parts per 1,000,000
Total solids	43.
Silica (SiO_2)	7.4
Iron (Fe)	0.1
Aluminum (Al)	0.53
Calcium (Ca)	1.4
Magnesium (Mg)	2.5
Sodium (Na)	3.6
Potassium (K)	2.3
Lithium (Li)	0.001
Manganese (Mn)	0.009
Barium (Ba)	0.02
Arsenic (As)	faint trace
Bicarbonate radicle (HCO_3)	3.1
Sulphate radicle (SO_4)	0.72
Nitrate radicle (NO_3)	8.80
Phosphate radicle (PO_4)	0.009
Chlorine (Cl)	11.
Free carbon dioxide (CO_2), 15 c. c. per liter.	

About 5 miles south of Manchester, near Temple's station, is the Campfield spring or well. It is situated in a hollow. The water flows from a bed of gravel covered by sand and loam. The water is shipped to Richmond, Norfolk, and other points, and is sold for table and medicinal use.

The following analysis is recomputed from that supplied by the company owning the spring.

Analysis of Campfield Lithia water.

(N. B. Tucker, analyst.)

	Parts per 1,000,000
Total solids	28.
Silica (SiO_2)	5.3
Iron (Fe)	0.3
Aluminum (Al)	0.11
Manganese (Mn)	trace
Calcium (Ca)	0.8
Magnesium (Mg)	0.9
Barium (Ba)	trace
Sodium (Na)	3.2
Potassium (K)	1.9
Lithium (Li)	0.05
Arsenic (As)	trace
Bicarbonate radicle (HCO_3)	8.0

Analysis of Campfield Lithia water—(Continued).

	Parts per 1,000,000
Sulphate radicle (SO_4)	2.4
Phosphate radicle (PO_4)	0.03
Chlorine (Cl)	5.2
Bromine (Br)	trace
Iodine (I)	trace
Free ammonia	0.002
Albuminoid ammonia	0.009
Nitrogen as nitrates	0.0
Nitrogen as nitrites	trace (?)

Free carbon dioxide gas, 27 c. c. per liter.

Besides these springs several others in eastern Chesterfield County are or have been of commercial importance, including the Urquhart Lithia spring, 4 miles from Richmond, and the Rocky Run south of Wiseville. A partial analysis of the water from the latter, furnished by the proprietor, David Adkin, is appended in recalculated form.

Partial analysis of Rocky Run Lithia water.

(Analyst unknown.)

	Parts per 1,000,000
Calcium (Ca)	40.
Magnesium (Mg)	0.46
Sodium (Na)	1.1
Potassium (K)	1.6
Iron (Fe)	1.1
Lithium (Li)	0.07
Carbonate radicle (CO_3)	1.2
Sulphate radicle (SO_4)	6.3

In the southern part of Chesterfield County are several springs from which water is or has been sold in Petersburg. One of these, the Patrol Oaks Mineral spring, three-quarters of a mile northeast of Ettricks, is a well rather than a spring. The water is clear, tasteless, and odorless; the flow is about 6 gallons per minute.

Another spring just north of the Powhatan highway bridge across Appomattox River is owned by a company and was once an important source of drinking water in the city of Petersburg. It is known as the Aqueduct spring. The water is still sold in the city, being delivered to houses at a nominal charge, and is the chief drinking water in Powhatan.

There are several springs along the valley side near Powhatan, some of the water coming from the Pamunkey (the contact of the basal pebble bed of this formation with dark clays of the Potomac being exposed just below the springs), and some of the water coming from under the Columbia loam which hides the older formations. The water is tasteless and odorless, clear and soft, and the slope above the springs has been so sparsely inhabited that the possible contamination of the sources has not called for investigation.

Wells.—Dug wells are almost the sole source of underground water for domestic supply. There are few drilled wells. The large manufacturing concerns and the railroad yards in Manchester either use city water or pump their own supplies from James River.

LOCAL SUPPLIES

Manchester, now a part of Richmond, owned its waterworks in 1906 and distributed filtered James River water. In the outskirts of the city, particularly to the west, are many shallow dug wells. The suburb of Swansboro, for instance, with a population of several thousand people, had no public supply system in 1906. The wells were dug through Lafayette cobble loams and decomposed granite, some obtaining water from the Lafayette and some from the granite. In places where firm granite comes near the surface more or less blasting has been done, usually with indifferent success. Where the cover of loam is thin, dug wells in such a thickly settled area are particularly liable to pollution; where 25 feet of loam, sand, and rotten granite are found above water, there is less danger; but wells should not under any circumstances be located within 75 feet of cesspools, privies, and other sources of contamination, and should be properly protected. In Manchester the local authorities have been closing dug wells as city service is extended.

At Bermuda Hundred on the bank of James River dug wells average 15 feet deep; the supply is not considered as satisfactory as that from springs, of which there are several along the foot of the low bluff facing the river. One of these, on property of the Farmville & Powhatan Railroad, has a bold flow of soft water, sufficient for the needs of several families.

At Centralia dug wells go down 18 to 20 feet, and obtain soft water from Columbia sands and clays.

There are in Chester about 50 dug wells 25 to 40 feet deep which get water from Columbia sands. Neither at Centralia nor Chester do wells go to hard rock.

At Ettricks, just across Appomattox River from Petersburg, dug wells are 12 to 45 feet deep, averaging 20 feet. They are not sunk to rock, but get water of varying quality, mostly soft, from beds in the Columbia.

Dug wells in Powhatan are sunk in Potomac and Columbia sands and gravels. They are about 20 feet deep, and some yield water of suspicious quality. Much of the drinking water used is taken from the Aqueduct Spring, previously mentioned.

Conclusions.—Satisfactory supplies for isolated residences and farm buildings can be had from dug wells. In thickly settled areas water much less liable to pollution can be had from drilled wells. Owing to the dissection of the Coastal Plain formations by the gorge of James River, flowing wells are not to be expected.

DINWIDDIE COUNTY.

General description.—Dinwiddie County, formed in 1752 from Prince George County, lies between Appomattox River and Nottoway River. Only a narrow strip along the east line of the county, which contains the city of Petersburg, is included in the Coastal Plain.

Most of this area has an elevation of more than 150 feet, and is included within the Lafayette and Sunderland terraces. Small patches of the Wicomico and lower terraces are found along Appomattox River near Petersburg. From an elevation of nearly 300 feet within a few miles of Petersburg there is an abrupt descent north to Lieutenant Run and Appomattox River, and a gentle slope southeastward. The southward-flowing streams which head in the divide, tributaries of Blackwater River, flow through swampy valleys.

Geology.—Crystalline rocks underlie the Coastal Plain section of the county at no great depth. Potomac, Pamunkey, and Chesapeake beds are all exposed in the immediate vicinity of Petersburg, but elsewhere are usually hidden by the Lafayette or the Columbia formations. The three, however, may be seen along Livetenant Run. Potomac arkosic sands and cobble beds are exposed near the mouth of the run at the crossing of the Norfolk & Western Railroad; Pamunkey greensands are visible at the east end of the dam at the city pumping station; and light-colored diatomaceous clays and dark greenish sandy clays of the Chesapeake, full of clam and scallop shells, are to be seen along the run and in its bed as far west as the Seaboard Air Line Railroad. Both the Potomac and Pamunkey are barely thicker than feather edges near Petersburg. The Chesapeake overlaps them and may have an extreme thickness of more than 100 feet at the eastern end of the county.

UNDERGROUND WATERS.

Occurrence and character.—All the Coastal Plain formations carry ground water, but the depths to the water table and the character of the water vary greatly. The chief sources of supply are the Lafayette and Sunderland formations, though a considerable number of wells are sunk in the Talbot and Patuxent sands and gravels near Appomattox River.

Springs.—There are numerous springs along hillsides and stream valleys, but they are usually small and of little importance, except for watering stock. No mineral springs from which water is shipped on a commercial scale are reported.

Wells.—Dug wells are the principal source of supply. Throughout the rural districts wood curbing is commonly used, but near Petersburg many dug wells are curbed with brick or stone. There are very few deep drilled wells in the Coastal Plain portion of the county.

LOCAL SUPPLIES.

The public supply system of the city of Petersburg gets water from Livetenant Run. There are, in the outskirts of the city, many shallow dug wells that vary greatly in depth and in probable freedom from pollution. Some dug wells in the city are used for boiler supply and other industrial purposes.

The only deep wells reported are those of J. B. Worth & Co., near the river. They are 100 and 150 feet deep, respectively, and yield under a pump 50 gallons of water per minute, which is used for condensing because of its temperature, 59° F.

Near Rowanta wells are 20 to 60 feet deep, most of them being about 25 feet. The deeper wells in this part of the county go through the Sunderland formation and get water, which is apt to be hard, from shell marl beds in the Chesapeake.

Conclusions.—In the rural districts dug wells not near sources of pollution, if properly protected against the entrance of surface impurities, will yield satisfactory supplies. In the city of Petersburg and its more thickly settled suburbs drilled wells are preferable for sanitary reasons. Flowing wells are not to be expected anywhere in the county.

ELIZABETH CITY COUNTY.

General description.—Elizabeth City County, formed in 1634 as one of the eight original shires of the Virginia colony, covers the tip of the peninsula, the strip of land between James and York rivers. The county contains the towns of Hampton and Phœbus, and the military post of Fort Monroe, near Old Point Comfort. At Old Point Comfort is the

Chamberlain Hotel, a famous health and pleasure resort; near Phœbus is a National Soldiers' Home; and at Hampton is the Hampton Normal and Agricultural Institute.

The county has a flat ill-drained surface, most of it being within the area covered by the lowest of the Columbia terraces, the Talbot. Elevations of about 30 feet are found in the low terrace along the Warwick County line. This plain grades very gently east to the salt marshes and mud flats of the shores.

Geology.—The yellow, buff, and gray loams and sands of the Talbot cover practically the entire surface of the county. The maximum thickness of the Talbot on the east side of the county is uncertain, but may amount to 50 feet. Below the Columbia lie Chesapeake, Pamunkey, Upper Cretaceous, and Potomac beds. The base of the Chesapeake beds on the east side of the county is about 600 feet below sea level. Beneath are about 150 feet of Pamunkey, 500 feet of Upper Cretaceous, and 900 feet of Potomac beds, the crystalline rocks lying perhaps 2,250 feet below sea level.

UNDERGROUND WATERS.

Distribution and quality.—The water table lies near the surface, and dug and driven wells get water at from 5 to 15 feet. The quality of the ground water is variable. Along the shores wells are liable to become salty under heavy pumping, and where the surface loams and sands are thin, wells go down into shell beds which yield hard water. The Chesapeake sands are uncertain water-bearers. The sands are local and seldom yield free flows. The water is iron-bearing in the upper beds and brackish in the deeper ones.

Springs.—There are no springs of commercial importance in the county. Most of the so-called springs are very shallow wells, dug in hollows where the water table is but a foot or two below the surface; many used for stock and household purposes have unsanitary surroundings and are liable to be badly polluted.

Wells.—Dug wells are mostly used, but there are many driven wells in the county. The deep drilled wells have been mentioned in the discussion of the Norfolk-Newport News area on pages 97-116.

LOCAL SUPPLIES.

Hampton obtains water from the Newport News Light & Water Co., a corporation that supplies surface water from a watershed in Warwick and

York counties to Newport News, Phœbus, the National Soldiers' Home, Hampton Normal and Collegiate Institute, and Fort Monroe. Within the corporate limits of Hampton are perhaps 3,000 persons, of whom fully one-half used this water in 1906. Another company, the Peninsula Pure Water Co., proposed to supply Hampton, Phœbus, Old Point Comfort, and the lower part of the county generally. The water was to come from ponds near Bethel, 9 miles from Hampton.

In the suburbs of Hampton about nine-tenths of the population use driven wells which get water at 10 to 12 feet in blue and white sands and marls. Much of the well water in Hampton is too hard for laundry use, while that near the shore is brackish; hence there are many cisterns. Near the Courthouse a well, elevation about 5 feet above mean high tide, dug for fire protection, is 25 feet in diameter and 22 feet deep; it passed through marl for 16 feet. It is now used for watering horses.

In the suburbs of Hampton some dug wells were still used as a source of drinking water in 1906, but their use was condemned by local health officials.

At Hampton Normal and Collegiate Institute most of the water used is supplied by the Newport News Co. There are several dug wells 10 to 15 feet deep, cased with 16-inch tile. The elevation of the Institute grounds, which border a tidal inlet, does not average over 5 feet; hence the well water has a high chlorine content. It is examined frequently for indication of possible contamination. The following determinations, made by W. S. Sweetser of the Institute, show the character of water from the better wells near the shores of lower Elizabeth City County.

Analyses of water from wells on grounds of Hampton Normal and Agricultural Institute.

(W. S. Sweetser, analyst.)

Location of well	Parts per 1,000,000	
	Chlorine	Total solids
Machine shop	59.4	265.0
Hospital	45.3	373.0
Trade school	28.8	401.0[a]
Whittier School	24.7	——

A well just outside the Institute grounds, close to the shore, gave water which contained 111 parts of chlorine per 1,000,000, but this water was pronounced dangerous.

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[a] High in nitrates; not used.

A 12-foot well dug on the Hemenway farm 6 miles from Hampton on Back River obtains water from a marl bed. The well is about 500 feet from salt water; the elevation is 6 feet, and depth to water 3 to 6 feet. The following partial analysis was made by the chemical laboratory of the Institute.

Analysis of water from well on Hemenway farm.

(W. S. Sweetser, analyst.)

	Parts per 1,000,000
Calcium (Ca)	188.
Magnesium (Mg)	16.5
Sulphates as SO_4	32.
Total hardness, as $CaCO_3$	38.4
Chlorine	113.

The Soldiers' Home, officially designated the Southern Branch of the National Home for Disabled Volunteer Soldiers, is just outside the municipal limits of Phœbus. Over nine-tenths of the water used is obtained from the Newport News Co. A few driven wells about the grounds furnish drinking water. Cistern water is used for flushing, and salt water for flushing and for fire protection.

In Phœbus there are many driven wells 13 to 15 feet deep which get water in Columbia gravels, under quicksand and yellow loam. The water is generally hard, but is used for all household purposes. In 1906 probably three-fourths of the population used such wells, the remainder taking Newport News water.

The Hotel Chamberlain uses some 60,000 gallons of water daily, about half of which is furnished by the Newport News Co., and half obtained from two dug wells 10 feet in diameter and 14 feet deep just outside the municipal limits of Phœbus on the Soldiers' Home grounds. The elevation of the surface at the wells is 8 feet above mean high tide. The wells are bricked, and the water rises from sands of the Talbot formation, normal water level being about that of mean high tide. Either well can be pumped dry in two hours by a 4 by 6 inch duplex steam pump running 60 strokes per minute, and to get the most water the wells are pumped together about 8 hours out of the 24. The wells were dug for the old Hygeia Hotel, which had to get water by boat from Norfolk. The well water, though slightly hard, is used as it comes from the well for all purposes except drinking; for drinking it is distilled. The flow from the deep artesian well at the hotel (see page 105) is used for flushing only.

At Fort Monroe three attempts to get good water by deep drilling ended with the well sunk to granite in 1902 (see page 100). About 1894 the

Government drove a series of wells on the mainland from which water was pumped to the fort by a pipe under the creek. The supply was satisfactory for a while, but other wells were driven nearby the city of Phœbus, and under heavy pumping the wells all became salty and were abandoned. In 1906, the post used for all purposes about 300,000 gallons of fresh water daily, supplied by the Newport News Co. Salt water is used for fire protection.

Conclusions.—Dug wells in places where the water table lies as near the surface as in Hampton County are peculiarly liable to be polluted, and their use on landholdings as small as the average house lot is altogether objectionable. Driven wells that go at least 10 feet below the water table are much to be preferred. The prospects for getting water of good quality by deep drilled wells in the eastern part of the county are decidedly unfavorable.

ESSEX COUNTY.

General description.—Essex County, formed in 1692 from Rappahannock County, lies on the south side of Rappahannock River, in the western part of the Coastal Plain.

Topographically the county resembles many other counties of the Coastal Plain. A high terrace, the Sunderland, with a slightly rolling surface, forms the divide between Rappahannock and Mattaponi rivers. Near Rappahannock River this terrace is deeply cut by creek valleys. Where the Wicomico terrace is missing bold headlands of the Sunderland overlook the river, and are noticeable features of the topography. The height of the Sunderland plain at the northwest end of the county is about 180 feet; at the southeast end about 150 feet.

Underlying the loams and gravelly beds of the Columbia terraces, the sandy and diatomaceous clays, clayey sands, and shell beds of the Chesapeake group can be seen in many road cuts. The basal part of the Chesapeake carries many indurated layers from a few inches to a few feet thick that are a source of trouble to well drillers. The dark greensand marls of the Pamunkey underlie the Chesapeake, but are not exposed at the surface anywhere in the county. The top of the Pamunkey is near sea level at the west end of the county, and 300 feet below at the east end.

UNDERGROUND WATERS.

Character and extent.—The chief sources of ground water are the sands of the Sunderland and Talbot terraces. Wells in headlands of the Sunderland formation, near Caret, Upper Mount Landing, and Dunnsville, are 50 to 60 feet deep, while back from the valley front and away from stream gulleys, as at Center Cross, are wells 15 feet deep or even less. On the low terraces along Rappahannock River dug wells are 10 to 25 feet deep, and in the lowlands at the head of Pianketank River are even shallower. The quality of the well waters varies greatly. The waters from the Columbia formations are generally soft and low in iron, but wells that strike the Chesapeake shell marls, either near surface or beneath the Columbia, get hard water.

Springs.—Springs are abundant, but only a small proportion are used for household supply, and none is of commercial importance. Practically all the springs are of the usual Coastal Plain type and most of them flow from the contact between the Chesapeake sandy clays and the clean, sharp sands of the Columbia formations.

None of the springs is now of commercial importance, though two have attracted attention. One of these, near Dunbrooke, is situated in a little hollow. Iron crusts lie about the spring and the water rises from a bed of sand in the Sunderland formation. The water is perfectly clear when fresh, but contains iron enough to leave a slightly yellow deposit about the spring. It has some local repute for medicinal value, but lack of convenient transportation facilities has retarded efforts to put it on the market.

Two springs, one of which was formerly a resort, are on land near Meade, owned by Charles C. Tombs, and now used as a camp-meeting ground. One is called a sulphur, the other a lithia spring, but both are of the same type and the waters are much alike. Meade camp-meeting ground is on the Sunderland plain in a grove of young hardwood. Spring-fed tributaries of a creek are eating into the plain, and just south of the camp-meeting grounds one of these has made a gulley some 40 feet deep. At the head of the gulley is the so-called lithia spring. It trickles from between dark greenish Chesapeake clay and overlying gray sands and iron crusts at the base of the Sunderland formation. The flow is not large, possibly two gallons per minute. In 1906, a shallow basin, 5 feet long, with wood sides, was the only improvement at the spring. The water is soft, contains a little iron, and is clear and odorless, with a very slight "iron" taste. The thickness of the overlying loams, the excellent surface drainage, the short time the grounds are frequented, and the sanitary precautions taken should keep the spring from becoming polluted.

The other spring, situated at the foot of a slope on the west side of the camp-meeting grounds, is now known as the iron spring but was called a sulphur spring. It flows from sands beneath a ledge of iron-stone near the base of the Sunderland formation. The water is perfectly clear and colorless in the basin, but contains a little iron, as is shown by yellow stains on the wood trough. It is said to have had a decided "sulphur odor," but this is now barely perceptible. Sixty years or more ago this spring was made a resort, and a hotel erected. The improvements have disappeared, and, though the water has a considerable reputation as a remedy for various complaints, it is not sold, though more or less is taken away by visitors. Field assays of the water of the two springs are given in table 6.

Other springs of note from their size, quality of water, or improvements, are owned by Armistead Ransome, of Dunnsville; J. H. Allen, of Layton; and Clayton Stafford, of Bowler's Wharf. Mr. Ransome's spring is said to flow 30 gallons per minute of soft water. The water from Mr. Allen's spring was once shipped to Washington, D. C., for use by a druggist. Mr. Stafford's spring flows 8 gallons per minute of clear water from the base of the Sunderland scarp. It is equipped with a hydraulic ram for household supply.

Wells.—Dug wells are the chief source of supply. In the Sunderland formation they are usually curbed with wood for 16 feet at the bottom; in the Talbot they are often curbed to the top.

Wells drilled deep enough to reach the water-bearing sands interstratified with rocky layers at the base of the Chesapeake are numerous along the Rappahannock River, there being fully 30 in the town of Tappahannock alone. They are mostly bored to get flows sufficient for domestic use, hence are of small diameter, usually 1½ inches. The reported depths vary from 250 to 270 feet below mean high tide; the reported heads vary from 10 to 30 feet above it.

LOCAL SUPPLIES.

At Tappahannock many dug wells get hard water at 12 to 15 feet. Nearly all the water now used for domestic purposes is obtained from flowing wells that strike sands underlying "rocks" at the base of the Calvert formation at a depth of 270 feet below mean high tide. The wells are mostly 1½ inches in diameter with a 2-inch casing driven through the Columbia sands and loams into the Chesapeake clays; the later wells frequently have a ¾-inch pipe to the bottom. The elevation of the terrace on which the town stands is 28 feet, but the flows, which vary with the tide, are usually small, from 1 to 2 gallons per minute. At no place in Tidewater Virginia, however, is there more economy in the use of water. Some wells supply two and even three houses, the water being piped in some instances several hundred feet, either directly from the well or from a tank at the well. There is no public supply system, but, as a safeguard in case of fire, a number of masonry tanks have been constructed by the town which are kept full by the overflow of certain wells.

The water is clear, and, though containing more lime than some Chesapeake flows, it is soft, adapted to all household purposes, and an admirable table water; a slight "sulphur" odor quickly disappears when the water stands in an open vessel. The temperature at the well mouth averages 61° F. A canning factory and a large pickling house use the water.

There are about 30 wells in or near the town, and, according to the driller who has sunk most of them, the succession of materials is as follows:

Generalized section at Tappahannock.

(Authority, O. D. Hale, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Sand and light clay	65	65
Blue clay with rock layers ½ inch to 6 inches thick; a little water at 135 feet	135	180
Mixed clay and sand	93	273
Thin crust of shell rock; variegated sand below; water-bearing	1	274

A noteworthy feature of the Tappahannock wells is the cypress "logs" which drillers report at about 60 feet; some of them, said to be several feet thick, cause much trouble in drilling.

Of the individual wells, the one at the pickle house of Donaldson & Shultz has the freest flow; it is on the river edge, and the mouth of the well is only 4 feet above tide. The flow in 1906 was 5½ gallons per minute, but is said to have been 12 gallons. Another good well is at the residence of B. P. Brockenborough on the edge of the terrace overlooking the river. It is cased with 2-inch pipe to the bottom, 272 feet, and has a 3-inch casing down 150 feet. The water, which is said to rise 16 feet above surface and more than 30 feet above mean high tide, is piped to the residence.

The following partial analysis of water from the well of R. T. Cauthorn shows how free from organic matter is the water from the principal water bed. Field assays of water from wells at Tappahannock and other places are given in table 9.

Partial analysis of water from well of R. T. Cauthorn, Tappahannock.

(G. H. Lehmann, analyst.)

	Parts per 1,000,000
Total solids	494.
Volatile matter	48.
Chlorine	1.95

Partial analysis of water from well of R. T. Cauthorn, Tappahannock—(Continued).

	Parts per 1,000,000
Nitrogen, as free ammonia	0.
Nitrogen, as albuminoid ammonia	0.
Nitrogen, as nitrates	0.
Nitrogen, as nitrites	0.
Sulphates, as SO_4	34.
Hardness	25.

Just north of Tappahannock, R. B. Brockenborough has four artesian wells at his large stock farm. One of these, at the manager's home, is used for domestic purposes; the other three, at barns and outbuildings, are for watering stock. In volume of flow and quality of water the wells resemble those in the village of Tappahannock. Up the river there are wells at the farms of J. P. Taliaferro and C. B. Mallory, southeast of Caret, and still farther upstream are those of Joseph Baker, J. H. C. Beverly, Mrs. M. S. Sale, and H. K. Baylor, all of which tap the same water bed.

West and south of Tappahannock artesian wells on Hoskins and Piscataquis creeks and along the Rappahannock include those of John Bradley, G. F. Croxton, and J. L. Kriete.

The first important group of wells down the river is at Ware's Wharf, where there are 5 which, though shallower than those at Tappahannock, going to an average depth of 185 feet below sea level, yield water of the same general character. The flows at individual wells vary with the tide, but range from ½ to 2 gallons per minute, with heads as high as 16 feet above sea level. The following record of one well was given from memory.

Record of well of R. L. Ware estate, Ware's Wharf.

(Authority, R. L. Ware.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Surface soil, clay and sand	30	30
Marl	140	170
Rocks	35	205

Another important group of wells is at Bowler's Wharf, 3 miles below Ware's Wharf. Here 10 wells get water from varying depths, the main flows being at about 165 to 180 feet below mean high tide. The water-bearing sand contains many rocky streaks, and the flows of nearby wells differ, the distribution of these impervious layers being a determining factor. Above the main flow is a weak one at about 130 feet, and below the main flow is another at about 240 feet. The record of the well drilled at the steamboat wharf ran about as follows:

Record of well of Garrett & Hunt, Bowler's Wharf.

(Authority, I. W. Hunt, owner.)

Material	Thickness (Feet)	Depth (Feet)
Water	10	10
Sand and gravel	15	25
Blue clay with shells	123	148
Sand	1	149
Strata of rock 1 to 9 inches thick and 6 inches to 4 feet apart; blue mud and shells, gray and red sand, and gravel between rocks; increased flow with each sand bed penetrated	18	167

This well, situated at an oyster house on the end of the wharf, flows a full 2-inch stream, 30 gallons per minute, at an elevation of about 5 feet above mean high tide and has a head of over 15 feet. It is one of the finest wells on Rappahannock River. In 1906, the flow was used as a table water on the steamboats plying between Fredericksburg and Baltimore, and for washing oysters.

Another fine well, at the canning factory of the Claybrook & Neale Packing Co., has a larger flow than that of Garrett & Hunt, namely, 45 to 50 gallons per minute at 5 feet elevation. Another well, with a flow of 17 gallons per minute at an elevation of 10 feet, is used by C. P. Garrett.

On the river shore 3 miles south of Bowler's Wharf, two wells have been drilled near a canning factory owned by Latimer Kriete to depths of 190 and 195 feet, respectively, and reach the same horizon as the wells at the wharf. One of the wells has a head of 30 feet above mean high tide, and flows 32 gallons at an elevation of 4 feet; the flow of the other was reduced by an accident in drilling. In a boiler the water has a tendency to foam and is said to form a white scale.

Just below Mr. Kriete's house, which stands on a projecting headland of the Sunderland terrace, a well was drilled to a depth of 300 feet, but, as the surface elevation is fully 65 feet, no flow was obtained.

Near Jones Point, 7 miles below Bowler's Wharf, are several flowing wells. One of these, owned by Garrett & Taylor, is 1½ inches in diameter and 221 feet deep. It flows 20 gallons per minute at 5 feet above mean high tide. The following record is reported:

Record of well of Garrett & Taylor on Jones Point, northwest of Butylo.
(Authority, I. W. Hunt, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Sand and clay	15	15
Gravel, surface water	3	18
Blue mud with beds of marl	107	125
Alternating layers of sand and rock; 22 rocks in all; first flow of water at 127 feet; main flow at 181 feet	106	231

Of the villages in the country using dug wells as sources of supply, Center Cross is one of the most important. The wells are sunk in the Sunderland formation to depths of 15 to 35 feet, and as a rule yield soft water. Information regarding dug wells at various places in the county is given in the following table:

Details of dug wells in Essex County.

Location	Depth of well *(Feet)*	Water bed	Quality of water
Banks	20–60	....	Soft
Dunnsville	32–80	....	Soft, hard
Caret	25–48	....	....
Center Cross	12–60	Loam and sand	Soft
Howertons	12–30	....	....
Laytons	15–30	Sand	....
Lloyds	25–30	....	....
Loretto	18–20	....	Soft
Mount Landing	10–60	Sand	....
Meade	20–50	....	....
Pedro	20–50	Sand	....

Conclusions.—Dug wells on high ground, if precautions are taken in locating and protecting them against the entrance of surface impurities, will yield satisfactory supplies. On the low terrace along Rappahannock River and its tributaries, flows of excellent water for domestic use can be had at comparatively low cost. There is a possibility of getting flows along Pianketank River, but the chances for flows at over 30 feet above sea level are poor. Flows of good quality and of equal or larger volume can undoubtedly be had from sands below those already developed.

FAIRFAX COUNTY.

General description.—Fairfax County, formed in 1742 from Prince William County, is in the northern part of the State, and is bounded on the east by Potomac River. The Coastal Plain portion along Potomac

River is about 16 miles long, but nowhere more than 6 miles wide. In it is Mount Vernon, the residence of General Washington.

The topography is rolling and broken as a whole. Along Potomac River are some nearly level stretches on low terraces, with elevations of 20 to 60 feet. Along the deeply scored sides of the Potomac valley, at higher elevations, are remnants of older terraces. An inlier of the Lafayette formation covers a considerable area north of Weddeburn and Dunn Loring, and caps the highest point in the county, Peach Grove Hill, at an elevation of 500 feet. The principal creeks in the Coastal Plain section of the county, Cameron Run, Accotink Creek, and Pohick Creek, are 8 to 15 miles long.

Back from the river the crystalline rocks are exposed in creek beds and on the valley slopes above. Near the river the sands, gravel beds, and clays of the Potomac group outcrop. The contact between the crystalline bed rock and the Potomac dips east fully 40 feet to the mile, so that at Mount Vernon the Potomac has a thickness of 525 feet. The Patuxent formation with its characteristic arkosic sands and dark clays includes fully 350 feet of the total thickness of the Potomac.

The maximum thickness of the Lafayette formation on the inlier north of Dunn Loring may be 40 feet. The Columbia formations vary in thickness from a thin edge to more than 35 feet.

UNDERGROUND WATERS.

Occurrence and character.—The decayed top of the crystalline rocks and the Potomac, Lafayette, and Columbia beds above contain ground water. The depth to water and the quality of the supplies vary greatly with the location of the wells and the character of the formations penetrated. One well may find plenty of water in Columbia gravel within a few feet of the surface, while another on a nearby slope, where the Columbia beds have been removed, may have to go deep into the Potomac beds or the granite to get a sufficient supply.

As in other counties along the "fall line," the water from the Lafayette and the higher-lying formations of the Columbia group is generally soft and slightly mineralized. On the lowest of the Columbia terraces the ground water in some places contains much iron; in others, it is excellent. The Potomac sands contain much water, but the sands that yield water freely are of irregular extent and the quality of the water varies. On high ground the crystalline rocks as a rule carry good water.

Springs.—Springs are numerous, but most of them are of small flow; only a few are of fair size. The waters are usually soft and pure and are often used for household purposes. From a few springs water has been shipped, but none is now of commercial importance.

Wells.—Dug wells, the main source of domestic supply, are frequently lined with stone and brick. Some are cased with large tile. Depths to water and the yield vary widely. Many wells are so situated and protected that there is little chance of pollution; others, particularly some on level stretches of the lowest terrace, have insanitary surroundings. Nearly all the drilled wells are 6 inches in diameter. Those on the lowest terrace get water from sands in the Patapsco or Patuxent formations of the Potomac group. Those on the high ground go into decayed or solid granite or gneiss. On the high ground no wells over 200 feet deep have been reported, but there are several of greater depth near Potomac River. The yield of the deep wells on high ground is seldom large, but nearly always sufficient for domestic purposes. Of the wells sunk on low ground to the Patuxent sands some yield large supplies, others only enough for the needs of a household of average size.

LOCAL SUPPLIES.

At the military post of Fort Hunt on Potomac River, 8 miles below Alexandria, all the water used is obtained from an 8-inch well sunk to a 13-foot bed of white sand in the Potomac group, 202 to 215 feet below the level of the terrace. The following record was obtained by Darton:

Record of well at Fort Hunt.

(Authority, W. C. Miller, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Yellow clay	24	24
Blue clay	15	39
Heavy sand and gravel, with little water	3	42
Red, blue, and yellow clays; streak of sandy blue clay with a little water at 122 feet	80	122
Red and blue clay	80	202
Coarse white sand with large supply of good water rising within 17 feet of surface	202	215

Pumping 53 gallons per minute lowers the water 15 feet. The water is pumped by an air lift to a cistern and is forced thence by a steam pump to a tank on a steel tower. The water is colorless, tasteless, and odorless. According to W. New, of the U. S. Surgeon-General's Office, the mineral matter is chiefly sodium sulphate with traces of calcium, magnesium, and iron salts. A partial analysis showed 342 parts of total solids and 5.14 parts of chlorine per million of water.

About a mile southwest of Fort Hunt, at the residence of Dr. Bliss, is a 65-foot drilled well that gets soft but slightly iron-bearing water from a Potomac sand or gravel bed. Dug wells in the vicinity get water from Columbia loams and sands at depths of from 15 to 25 feet.

A mile northwest of Fort Hunt, at Riverside Park near the mouth of Little Hunting Creek, on property owned by the Riverside Brick Co., are two 6-inch wells which get water from Potomac beds. They are said to be over 100 feet deep. Neither gives a flow, the elevation of the surface being about 20 feet. Each affords a fair supply of good, though slightly iron-bearing water. Near Hunters station, on the Washington, Alexandria & Mount Vernon Railroad, a drilled well gets good water from a bed of white Potomac sand at 165 feet.

At Arcturus station, on the same road, household supplies are obtained from dug wells. The deepest of these, about 30 feet, owned by H. C. Pilling, strikes a bed of sand and mud containing "logs," and yields water high in iron. A gasoline engine pumps the water to a tank.

At Mount Vernon water for domestic purposes is obtained from an 8-inch artesian well 525 feet deep. The well is near the edge of the river, the well mouth being about 7 feet above high tide level. Little water was found in the basal beds of the Patuxent formation, and the casing was pulled back. The present supply, which rises within 6 feet of the surface, its level fluctuating with the tide, comes from a sand and gravel bed at 345 feet. The following log, kept by W. H. K. Shannahan, the driller, was furnished by William Archer, of Mount Vernon.

Record of well at Mount Vernon.

(Authority, J. H. K. Shannahan, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Blue and red clay	10	10
Gray clay	15	25
Hard green and blue clay	25	50
Hard green, blue, and brown clay	25	75
Sandy brown clay	25	100
Coarse green water-bearing sand; bad water, has the odor of marsh water, very unpleasant	25	125
Brown and green clay and gray sandy clay	25	150
Marsh clay	50	200
Very hard and dry brown, green and blue clays	100	300
Light green sandy clay	25	325
Light green sand, water-bearing below 340 feet, source of present supply	25	350
Clays	165	515
Sand, little or no water, and that sulphur-bearing	10	525
Bed rock	525	

The water supply is good. A steam pump lifting 50 gallons per minute from the well to a tank on top of the bluff, 175 feet, lowers the water about 9 feet. The water is soft and works nicely in a boiler, making little scale.

Water for washing, flushing, and greenhouse use at Mount Vernon is obtained from springs developed by drains along the face of the river bluff. The mode of development is described on page 62.

On Sandy Point a deep well was sunk for H. L. Cranford some years ago. The following record has been published:[a]

Record of well on Sandy Point, 2 miles southwest of Gunston.

(Authority, L. W. Shepard, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
White and yellow clay	20	20
Very soft blue swamp muck	80	100
Gravel and sand; water	15	115
Clay	15	130
Gravel and sand; water	10	140
Clay	10	150
Fine sand and clay; water	60	210
Clay	20	230
Fine sand and clay	25	255
Clay	9	264
Small pebbles and lignite	6	270
Clay	15	285
Soft rock; no water	5	290
Rock	270	560

The well was dynamited at 265 feet. The water from this point rose within 24 feet of the surface or about mean high tide level, and, according to the driller, showed tidal fluctuations of 3 feet.

Near the village of Accotink dug wells vary from 15 to 90 feet in depth, according to location, and get water of varying quality from Columbia and Potomac sands and pebble beds. The deepest of these dug wells is owned by J. P. H. Mason. It is on a hill 1½ miles north of Accotink and about 180 feet above tide level. The well, which is 91 feet deep, went through these materials.

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[a] Darton, N. H., Artesian water prospects of the Atlantic Coastal Plain, Bull. U. S. Geol. Survey No. 138, p. 178.

Record of dug well one and one-half miles north of Accotink.

(Authority, J. P. H. Mason, owner.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Very hard red gravel	18	18
"Fullers earth"	10	28
Light bluish sandy clay	16	44
White clay and sand, a little water	5	49
Light bluish sandy clay; water at 88 feet	42	91

Another well, 300 yards east of this, found a little water at 56 feet and no water below for 60 feet.

On the inlier of Lafayette formation that extends from near Dunn Loring to Peach Grove and Freedom Hill, dug wells are from 20 to 40 feet deep. The water, which is generally soft, is obtained from the Lafayette, and where that formation is thin, from decomposed crystalline rock. The deepest well reported in this section, 130 feet, is that of R. H. Watts, about 1½ miles east of Freedom Hill. It is said to have been drilled through clay and gravel and to have struck no rock. The first water was struck at 30 feet, but the main supply, about 10 gallons a minute, comes from 120 feet.

Near Springman dug wells are 20 to 60 feet deep, about 50 feet being the most common depth and the one at which most water is obtained. At Pohick, Springman post-office, a well at the Methodist Church is 80 feet deep, obtaining water at 70 feet, but the church is on top of a hill.

The town of Falls Church had no public water supply system in 1906. The inhabitants relied chiefly on dug wells 10 to 35 feet, most of which yielded soft water.

At West Falls Church a 120-foot well, drilled for the Washington, Alexandria & Falls Church electric road, obtained in "granite" an irony water which is not used.

Particulars regarding dug wells at some villages are given below:

Details of dug wells in Fairfax County.

Location	Depth *(Feet)*	Water bed	Quality of water
Accotink	25-91	Sand and clay	Hard
Dunn Loring	20-65	....	Soft
New Alexandria	10-20	Sand and loam	Soft
Lorton Valley	20-50	Sand and gravel	Soft

Conclusions.—Good water can be had in the Coastal Plain portion of Fairfax County by both dug and drilled wells. At most places the former will furnish ample supplies for ordinary purposes, and if properly located and cased will be safe. Drilled wells near Potomac River will find good supplies in the Patuxent sands. Flowing wells, except at the water edge, are not to be expected.

GLOUCESTER COUNTY.

General description.—Gloucester County, formed from York County in 1861, lies between York River and Pianketank River.

Topographically the county is one of the most interesting in Tidewater Virginia. Part of the surface is included in the Sunderland terrace. The highest points in this terrace, about 125 feet, are in the northwest corner of the county; the lowest points have an elevation of 100 feet. The Talbot[a] terrace covers most of a triangular area between Severn River, Mobjack Bay, York River, and a line from Gloucester Point past Hayes' Store and Roanes to Pianketank River; this line follows a sharply defined scarp, the most marked and unmistakable terrace scarp in the Virginia Coastal Plain. From the foot of this scarp at an elevation of about 25 feet the Talbot terrace slopes very gently eastward to sea level, fading away in strips of salt marsh and wet ground.

Geology.—The Columbia formations are prevailingly loamy at top and sandy below; along York River large ice-borne boulders are found in the lower formations. Beneath the Columbia are the sandy clays, sands, and marl beds of the Yorktown and St. Mary's formations of the Chesapeake group. The marl beds weather light- or bright-colored, but are dark greenish or bluish below water level. The total thickness of the Yorktown formation may be 100 feet. The thickness of the other Chesapeake formations under cover, the St. Mary's, Choptank, and Calvert, is not determinable from the well records available, but the base of the Chesapeake lies about 200 feet below sea level at the western corner of the county, and 300 feet deeper on the shore of Mobjack Bay. Below the Chesapeake lies 150 to 200 feet of Pamunkey greensands, the more glauconitic and porous making the "black sand" of well drillers, while below these are the Upper Cretaceous formations.

UNDERGROUND WATERS.

Distribution and quality.—Both the surficial deposits and the deep sands, except at the east end of the county, contain abundant supplies of water. The quality varies greatly; probably no county in Tidewater Virginia can show more variety. On high ground the shallow water is soft and low in iron, except in Chesapeake marl beds. Near Mobjack Bay and at some points along York River the shallow water is of indifferent quality, very hard, high in iron or brackish; at some places it is excellent. The artesian waters show as great variation. At the west end of the county they are soft, clear, and fresh; at the east end they are barely potable, containing salt, sulphate and bicarbonate of soda, and at some wells iron. They are as a rule sulphur-bearing.

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[a] The writer believes that the terrace that occupies the greater part of the area mentioned is to be correlated with the Pamlico terrace of North Carolina.

Artesian waters under moderate cover, 50 to 100 feet, are found in the eastern end of the county. They have low heads, 2 to 5 feet above mean high tide, and lie in irregular and discontinuous sand and shell beds in the Yorktown formation. The waters as a rule are clear and bright, but more or less limy, and in places very hard and iron-bearing. The deeper sands of the Chesapeake group give higher heads, up to 35 feet, and at some places larger flows. Very soft waters, resembling those of the basal Chesapeake beds, are found in the Pamunkey under the western part of the county, but to the east the Pamunkey sands, like the Chesapeake, as suggested by Darton,[a] probably become too fine to transmit water readily. The flows decrease in volume and cease, no flow being known from the Pamunkey east of Gloucester Point. Little is known of the Upper Cretaceous formations, but in the eastern portion of the county deep wells get waters presumably from these formations, that vary in character from the soft, alkaline, slightly sulphur-bearing flow at Gloucester Point to the highly mineralized, saline, ferruginous waters found near Severn River. The Potomac beds have not been tapped within the county west of Selden. They undoubtedly contain potable water in abundance as far east as Claybank.

Springs.—Springs are abundant. Most of them flow from Columbia sands; some from Chesapeake marl beds. Yields are generally small, averaging at such springs as are in any way improved, 5 to 10 gallons per minute; flows as large as 20 gallons per minute are rare. A considerable number are still used for household supply. No spring yields water for shipment in commercial quantities, and none is a health or pleasure resort. A few that have attracted notice by reason of size, location, or quality of water are owned by Dr. C. H. Bradford, near Dutton; F. E. Du Val, near Cash, a large marl spring; Thos. Dixon, Jr., 2 miles west of Dixondale, a bold flow of soft water known as the Cow Spring; C. J. Roane, near Woods

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[a] Darton, N. H., Artesian water prospects of the Atlantic Coastal Plain. Bull. U. S. Geol. Survey, No. 138.

Cross Roads, irony water; W. R. Stubbs, near Pinetta, hard, iron-bearing water; and G. P. Brown, near Wan.

At Gloucester Point a spring of soft water rises through surface sand from shell-rock in the Yorktown formation. The water is much used by fishermen for boat supply, as it is said to keep well. The flow is about 1½ gallons per minute.

Wells.—Dug wells are practically the sole source of supply on ground over 40 feet above tide level. On lower ground are also dug and driven wells, the latter being particularly numerous toward the east end of the county.

LOCAL SUPPLIES.

At Gloucester are some 15 dug wells from 25 to 40 feet, most of which are lined with brick. There are no springs close to the Courthouse, which is on a ridge, but there are plenty with perennial flow along neighboring creeks. Owing to good drainage, the thick cover of loam, and the depth to water table, dug wells at Gloucester are not likely to be polluted if ordinary precautions are taken to prevent the ingress of surface water.

Near Achilles a number of deep driven wells that do not flow yield water of varying quality. One owned by B. A. Rowe gives water that is reported to work well in a saw-mill boiler. The water may come from beds of Chesapeake age.

The wells along York River from Puropotank Creek to Gloucester Point tap the Chesapeake, Pamunkey, and Upper Cretaceous sands. In general the wells flow soft, alkaline water suitable for all household purposes. The height to which water rises varies; the Chesapeake sands give heads of from 10 to 30 feet, but the Pamunkey gives reported heads of 35 feet at Cappahosic and of 25 feet at Timberneck Creek. The flow from the Upper Cretaceous sand, at Gloucester Point, has a head of but 10 feet.

A well 3 miles southwest of Signpine, on a tidal inlet, found salt water at 13 feet, brackish water at 33 feet, and good artesian water at 196 feet, as shown by the following log:

Record of well of R. C. Coleman, 3 miles southwest of Signpine.

(Authority, R. C. Coleman, owner.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Yellow sand, salt water at 13 feet	13	13
Lighter colored sand, white at base; brackish water at 33 feet	20	33
Blue marl or "marsh mud"	155	188
Quicksand	9½	208½
Hard shell-rock	½	210
Sand; main flow	1	211
Elevation of surface 3½ feet.		

At Allmondsville several wells have been sunk for oyster houses and boiler supply. The reported depths are about 300 feet, the flow coming from Chesapeake sands. The alkaline water has a slight sulphur odor; it neither pits nor scales a boiler, but has a tendency to foam. A field analysis of the water from one well is given in table 8.

On Jones Creek, B. B. Weaver has a 336-foot well that flows 5 gallons at 5 feet above mean high tide. The water comes from medium fine quartz sand containing much dark green glauconite. The owner dammed a small run and put in a water wheel which he belted to a "bulldozer" pump that forces the water to a tank on a tower near the house; the house is 25 feet above the spring, and the total lift to the tank about 50 feet. Table 8 contains a field assay of a sample of the water.

The well at Cappahosic, 415 feet deep, found no flow in the Chesapeake sands, and the Pamunkey flow is of moderate volume. The owner has harnessed the well to a small ram, a flow of 3 gallons per minute, with a drop to the ram of 6 feet, being sufficient to lift all water needed for domestic use to a tank in the house 40 feet above the river. The overflow from the ram is piped to neighbors' houses, one being 300 yards distant.

The decrease of yield in the Chesapeake and Pamunkey sands near the mouth of York River is shown by a well sunk for James Brown by a driller familiar with local conditions. This well, on Carter Creek, about half a mile from the mouth, found water from 60 to 80 feet in coarse gravel, and no more till a very weak flow at 535 feet; sinking to 610 feet brought no increase in flow and the well was abandoned.

Near Timberneck Creek are artesian wells which get water from the shell beds in the Yorktown formation. One of these, 65 feet deep, at the residence of Charles Catlett, is used for household supply; two other wells sunk to the Pamunkey gave flows of sulphur-bearing water. The flow from the shallow well has a head of 4 feet and shows large tidal fluctuations. The water is clear but hard.

On the beach at Gloucester Point is a well 690 feet deep which gets water from the Matawan; no flows were found, according to the driller, in the Pamunkey or Chesapeake beds, and the Matawan flow is small (2 gallons), and of low head, 10 feet. The well was sunk for public use. The water has a slight sulphur odor, is alkaline, and contains more salt, sulphate of soda, and lime than the wells up the river. In a boiler it foamed badly. A field analysis is given in table 10.

The following record is reported from one of the flowing wells on Pianketank River. The water is probably from the base of the Chesapeake group.

Record of well of R. J. Bristow, 3 miles east of New Upton, on Pianketank River.

Material	Thickness *(Feet)*	Depth *(Feet)*
Sand, water at 8 feet	**15**	**15**
Clay	**15**	**30**
Sand	**4**	**34**
Blue sand marl; water at 42 to 46 feet	**201**	**235**
Sand, very small flow of water	**2**	**237**
Marl	**148**	**385**
Soft rock; flow of water, about ¼ gal. per minute, at 415 feet	**30**	**415**

Near Severn River are several deep wells notable for their highly mineralized waters. All the flows contain considerable salt in addition to sodium carbonate or bicarbonate, and some of the flows are decidedly iron-bearing. The yields vary decidedly, but as a rule are scanty.

At Eagle Point, the country seat of the late Joseph Bryan, several attempts were made to get a sufficient flow of potable water. The most important attempt was a 6-inch well 1,004 feet deep. It penetrated several water-bearing beds but found no water that would overflow, though the elevation of the surface is but 5 feet above tide. Another well, 900 feet deep, yields a scanty flow of clear, saline, alkaline water. (See table 11 for field assay.) A well 100 feet deep gets a flow of decidedly hard water from a shell bed in the Yorktown formation. Cistern water is used for most purposes. Nearby at the residence of A. W. Withers is a 6-inch well 605 feet deep, that taps Upper Cretaceous beds. It flowed, at an elevation of 6 feet above tide, 69 gallons per minute of salty, ferruginous, bicarbonated water that readily corrodes steel pipe. The water is too salty to be palatable. (See table 10.)

At Severn a well 610 feet deep found water at the base of the Pamunkey. The owner gave the following record from memory:

Record of 610-foot well of J. N. Shackelford, near Severn, Gloucester County.

Material	Thickness *(Feet)*	Depth *(Feet)*
Clay	1	1
White sand	6	7
Yellow and reddish sand; water	1	8
Blue shell marl, small shells	10	18
Dark gray sand, water-bearing; "water contained lime but washed well"	6	24
Dark marl and sand mixed	46	70
Light bluish marl containing a few shells, and mud	355	425
Fine black sand "almost as dark as gunpowder" with one white grain in 50 black; water-bearing but water did not rise to surface	15	440
Soft dark or greenish mud, very few or no shells	135	575
Black sand in hard layers, water-bearing, flow 1 gallon in 5 minutes at 5 feet elevation above tide	55	610
Below the rock was clean gravel "like fine hail" pebbles size of wheat grains, clear or occasionally bluish; this gravel contained water but the gravel and sand choked the pipe and it was pulled back to 575 feet		

The water is clear, but highly mineralized, containing considerable salt. It has been drunk as a medicinal water. (See table 10.)

Some particulars of dug wells, reported by postmasters, at various points in the county are shown below in tabular form:

Details of dug wells in Gloucester County.

Location	Depth *(Feet)*	Water bed	Quality of water
Belroi	10–20	Sand	Hard and soft
Cash	30–45	Sand and marl	Hard
Dutton	18–50	Sand	Soft
James Store	25–50	Sand	Soft
New Upton	35–40	Sand and marl	Soft and hard
Ordinary	10–35	Sand	Hard and soft
Pinetta	25–40	....	....
Roanes	20–30	Sand and marl	Hard
Signpine	40	Sand and marl	....
Woods Cross Roads	30–50	Sand and marl	Soft and hard
Whitmarsh	18–60	Sand	Soft
Wicomico	10–40	Sand and gravel	....

Conclusions.—Artesian water can be had under the whole of Gloucester County, but the wells already dug demonstrate that liberal flows of good quality can not be expected east of Gloucester Point. Excellent water can be had in the western part of the county under heads of 30 to 35 feet above tide. At Gloucester Courthouse soft alkaline water can be had by a well less than 500 feet deep, but a deep well pump must be used as the water will probably not rise to within 40 feet of the surface.

GREENESVILLE COUNTY.

General description.—Greenesville County includes the extreme southwest corner of the Virginia Coastal Plain, south of Meherrin River, and its southern boundary is the North Carolina-Virginia state line. The Coastal Plain portion of the county lies east of the Atlantic Coast Line Railway, and has an area of about 70 square miles.

The surface shows considerable diversity of relief but much of it is low, and is included within the valleys of Meherrin River, Fontaines Creek, and tributary swamps. The general slope is east. Along Meherrin River the lower Columbia terraces are extensive. The maximum elevations of the Coastal Plain area in this county have not been determined, but the Sunderland terrace is a less important feature of the topography than in counties to the north. Elevations above sea level range from 200 feet, west of Jarratt, to 20 feet along Meherrin River.

Geology.—Granite outcrops in the bed of Meherrin River near Emporia, and lies less than 50 feet below the surface in the town. Near the river the granite is overlain by Columbia gravels, sands, and loams, which also mantle the surface in the vicinity of the town and along the railroad to the south.

Potomac sands overlie the granite a short distance east of Emporia, but are not exposed along Meherrin River nor anywhere within the county. There is nothing to indicate the presence of Upper Cretaceous or of Pamunkey (Eocene) beds. Chesapeake marls are exposed in places by pits from which the marl was dug.

UNDERGROUND WATERS.

Distribution and quality.—The Columbia and the underlying Chesapeake or Potomac sands carry waters that show considerable variation in quality. Sufficient water for household needs can be had anywhere in the Coastal Plain portion of the county at small cost. For larger supplies groups of driven or bored wells have been put down in the Columbia sands, and at least one well has been drilled deep into granite.

LOCAL SUPPLIES.

At Emporia water for boiler supply has been obtained from dug, bored or driven wells. The Emporia Manufacturing Co., in 1905, had 6 bored wells, 24 feet apart, with 4½-inch casing, and a 2-inch suction pipe having a slotted brass strainer 2 feet long inside the casing; the yield was about 60 gallons per minute of hard water. Soft water was found at 22 feet. The company had also a series of 20 bored wells 16 feet apart, 2 inches in diameter, with 18-inch screens, and only about 22 feet deep. The water normally stood within about 10 feet of surface and the combined yield to pump was 70 gallons per minute. Granite is found at 32 feet.

The town of Emporia has a 600-foot drilled well, described on page 93; it furnished unsatisfactory water from crevices at several depths.

HANOVER COUNTY.

General description.—Hanover County, formed in 1720 from New Kent County, lies between Chickahominy and Pamunkey rivers, but only that part east of the Richmond, Fredericksburg & Potomac Railroad is within the Coastal Plain province. This part, probably 100 square miles in extent, contains several important settlements, the largest being Ashland.

The topography has the varied aspect common to other counties along the "fall line." The Lafayette and older Columbia terraces have been deeply trenched by tributaries of Chickahominy and Pamunkey rivers; maximum elevations are 200 to 225 feet near Ashland, Merryoaks, and Ashcake, while the swamp along Chickahominy River is 50 to 80 feet, and the flood plain or first bottom along Pamunkey River, is 10 to 30 feet above sea level. The Sunderland plain east of Ashland may be 160 to 180 feet high. The Wicomico plain lies along Pamunkey River from near Hanover to Doswell. At the latter place it forms the "second bottom" at an elevation of 60 to 80 feet above tide. A lower plain is well developed near New Castle bridge, where its surface is 25 to 40 feet above sea level. The Wicomico is not well shown in the Chickahominy valley.

Geology.—Granite underlies the Columbia deposits south of Ashland, and the Triassic sandstones outcrop north of Ashland, near North Anna River. Above this basement to the east are Potomac, Pamunkey, and Chesapeake deposits. The Potomac at Belamar is represented by a few feet of dark bluish shale, and on the North Anna near Doswell by arkosic sands and sandstones of the Patuxent formation. The exposures of Eocene deposits along Pamunkey River from Wyckham to Piping Tree Ferry were visited by Conrad and by Rogers over 70 years ago, and have been examined by many geologists since. The beds consist of dark green sands containing fossil shells which in places form shell-rock. Most of the material exposed is part of the Aquia formation. No Pamunkey (Eocene) beds are exposed in the Chickahominy valley. The Chesapeake (Miocene) beds, chiefly of the Calvert formation, overlap the Pamunkey. They comprise dark greenish sandy clays, which in places contain many fossil shells and in places are full of diatoms. The thickness of the Chesapeake beds varies from a feather edge to possibly 100 feet on the east side of the county.

The Lafayette and Sunderland formations overlap the granite and the Cretaceous, Eocene or Miocene beds to the west, the Lafayette extending an unknown distance westward. The Sunderland contains numerous large boulders of crystalline rocks, evidently ice-borne, and near Wyckham its scarp is as thickly strewn with boulders as a New England hill pasture. On the Wicomico plain along Pamunkey River these sub-angular boulders of gneiss and schist are dug out in tilling fields and used for well-casing, foundation-stone, flagging, etc.

UNDERGROUND WATERS.

Distribution and character.—Water-bearing beds occur in the Potomac, Pamunkey, Chesapeake, and Columbia deposits. The deeper Potomac and Pamunkey waters, as indicated by wells in King William County, are probably of good quality. The water from the Columbia sands is as a rule soft.

Springs.—Springs of the usual Coastal Plain type are numerous, but comparatively few are used for household supply and from none is water sold regularly. The quality of the spring waters varies from hard or iron-bearing to very pure and soft.

One spring of note is near the residence of T. A. Taliaferro about 1½ miles southeast of Pole Green. This spring rises as a bold flow from a bed of white sand (Sunderland) near a little run tributary to Beaver Dam Creek. The spring is said to rise from a depth of at least 20 feet, as a pole can be forced down into the sand to that depth. The flow, about 15 gallons per minute, is clear, soft, and light. The owner furnished an analysis that has been recomputed to express results in the form used by the Federal Survey.

Analysis of water from spring of T. A. Taliaferro, southeast of Pole Green, Hanover County.

(Henry Froehling, analyst.)

	Parts per 1,000,000
Total mineral solids	19.
Silica (SiO_2)	6.2
Iron (Fe)	0.08
Aluminum (Al)	0.11
Manganese (Mn)	0.02
Calcium (Ca)	0.7
Magnesium (Mg)	0.3
Sodium (Na)	2.2
Potassium (K)	0.8
Lithium (Li)	0.01
Arsenic (As)	trace
Bicarbonate radicle (HCO_3)	2.7
Sulphate radicle (SO_4)	2.3
Phosphate radicle (PO_4)	0.03
Chlorine (Cl)	3.1
Iodine (I)	trace
Free carbon dioxide gas 64 c. c. per liter.	

No improvements had been made at this spring when it was inspected, nor was the water being sold.

Other springs of more or less note in the Coastal Plain section of Hanover County are those of H. Carter Ridd, of Beaver Dam; of M. C. and C. H. Tate, at Ruel, which give iron-bearing water; and a small spring of E. G. Gwathmey, near Taylorsville, said to yield sulphur water.

LOCAL SUPPLIES.

Dug wells at Hanover average 20 to 30 feet deep, though one was dug 60 feet. The water from most of the wells is called "medium soft." The deeper wells go through the Columbia gravels and sands into the Chesapeake beds, and if they strike shell marl the water becomes hard. The 60-foot well found a little hard water at 20 feet on top of a dark. greenish sandy clay of the Chesapeake group, but none for 40 feet below.

At Ashland most of the water used is obtained from dug wells; enough for a family of ordinary size can be obtained by digging 18 or 20 feet. Because of the level surface of the ground and the shallow depth of the water table there is danger of pollution; hence some people use only cistern water for drinking. At Randolph-Macon College cisterns of large size, kept securely locked, are filled during late fall, winter and early spring; the supply being accumulated after leaves have fallen and migratory birds have left the region.

Where there is no danger of pollution from nearby cesspools or wells with unsanitary surroundings, good water from dug wells is had by digging to below water level, dumping in several feet of clear, coarse gravel, and using tile curbing with tightly cemented joints, the top length projecting a foot or so above surface.

Several attempts to get water by drilling have been made at Ashland. One well at Randolph-Macon College, sunk about 100 feet, furnished satisfactory supplies for about ten years, and then was abandoned because an influx of sand choked the pump. A deep well intended to furnish a supply for the college and the town is on the grounds of the Henry Clay Inn. This well, 365 feet deep, went through the Lafayette and obtained its supply from the sandstones of the Newark. The following record is that furnished by the driller:

Record of deep well of Ashland Water and Light Co., at Henry Clay Inn, Ashland.

(Authority, Sydnor Pump and Well Co., drillers.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Earth	64	64
Rock	77	181
Sandstone	26	307
Soft brown shale	58	365
Slate	——	365

The following record of a well near Ashland is from Darton's bulletin.[a]

Record of well near Ashland.

Material	Thickness *(Feet)*	Depth *(Feet)*
Clay and soil	20	20
Gravel and sand	22	42
Blue clay with beds of fine sand	37	79
Stratum of sandstone	6	85
Disintegrated stone, with water in its upper portion	35	120
Granite	20	140

In 1910, a public supply system, taking water from two deep wells, was installed.

On the lower terrace near Pamunkey River many shallow wells 10 to 15 feet deep get water enough for family use, but are frequently filled by surface water during rains, and are not considered wholly safe. A deep well sunk for locomotive supply by the Richmond, Fredericksburg & Potomac Railroad, near Doswell, elevation 55 feet, obtained, from the Newark rocks at a depth of about 300 feet, hard water, which rose to within 3 feet of the surface. The supply was either insufficient or unsatisfactory, for the well was abandoned by the railroad company and later covered in widening the grade.

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[a] Darton, N. H., Op. cit. p. 179.

About Wyckham, wells on the Sunderland plain get soft water at depths of 30 feet or less. Near Wyckham station on the scarp above the Wicomico plain an attempt to get water by digging into the Chesapeake marls and clays was unsuccessful. The following section was furnished by W. W. Dyson, superintendent of Hickory Hill farm.

Record of 75-foot well at Hickory Hill, Wyckham.

(Authority, W. W. Dyson.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Loam and pebbles	5	5
Red clay	4	9
White "fuller's earth"	10	19
White and purplish "fuller's earth" with iron stains	10	29
Dark bluish black "fuller's earth"	8	37
Blue gravel and sand, pebbles large as hens' eggs	3	40
Blue sand	2	42
Shell marl, very hard, full of scallop and clam shells and sharks teeth	11	53
White sand, water-bearing	1	54

The water rose to the top of the marl. It tasted strongly of iron, and was so hard that it could not be used for washing, consequently the well was filled.

Shallow well conditions at a number of points in the Coastal Plain section of the county are given in the following table:

Details of dug wells in Coastal Plain portion of Hanover County.

Location	Depth *(Feet)*	Water bed	Quality of water
Belamar	12–100	Sand and rock	Soft and hard
Doswell	15–35	Sand	Soft
Beaverdam	15–30	Sand	Soft
Pole Green	30	Sand	Soft
Ruel	30	Sand	Soft

Conclusions.—There is little chance in Hanover County for artesian water that will rise above tide level, but in the eastern part of the county water of good quality and softer than that obtained by dug wells can be had by drilling. The Newark rocks are uncertain water-bearers, and though water can probably be had from them the quality and yield can not be predicted; both may be good, as at Ashland, or poor, as at Doswell.

HENRICO COUNTY.

General description.—Henrico County, formed in 1643 as one of the original shires of Virginia, lies between James and Chickahominy rivers, part of the county being in the Coastal Plain and part in the Piedmont Province. Richmond, the capital of Virginia, a prosperous manufacturing city, had a population of 127,628 in 1910. The area of the Coastal Plain portion is about 350 square miles. Outside the city limits are a number of suburbs, chiefly residential, such as Barton Heights, Brookland, Ginter Park, and Highland Springs. The population of the county, exclusive of Richmond, was 23,437 in 1910.

Away from the railroads and the immediate vicinity of Richmond the county contains few villages of importance. Along the James River are several famous estates, and one of the largest single farms in the State, measured by land under cultivation, is about 15 miles below Richmond.

As Henrico County lies partly in the Coastal Plain and partly in the Piedmont Plateau the topography is characterized by the gently undulating remnants of the high Lafayette or Sunderland plains on the interstream areas, with precipitous scarps along the gorge of James River, the gorge at Richmond being nearly 250 feet deep. The Lafayette plain has an elevation of 200 to 225 feet. The lower terraces are not well developed near Richmond, but can be traced along the James River valley below.

The Coastal Plain area contains few creeks or runs more than a few miles long. Those emptying into the James such as Shockoe, Gillies, and Almond creeks, have cut sharp valleys which are marked features of the topography. Along Chickahominy River is a cypress swamp, lying 50 to over 100 feet above tide level and in places over a mile wide.

Geology.—The gray granite-gneiss over which James River flows at Richmond is exposed at higher elevations in railroad cuts west of the "fall-line," as at Glen Allen. It dips eastward from the "fall-line" about 40 feet to the mile, and above it lie Potomac, Pamunkey, and Chesapeake beds, all of which outcrop in the city limits of Richmond. The Patuxent formation, with arkosic, incoherent or indurated sands full of pebbles, cobbles, and clay balls, may be seen along Gillies and Almond creeks. The Pamunkey greensands and the Chesapeake diatomaceous clays are exposed at the famous outcrop on the west bank of Shockoe Creek, just below the plant of the American Locomotive Works, where, in a bluff about 40 feet high, dark argillaceous Pamunkey greensands of the Nanjemoy formation grade into dark diatomaceous clayey Chesapeake sands of the Calvert formation. Higher up the run are many outcrops of the Calvert formation full of shells. North of the city, near the State Fair grounds, dark fossiliferous Chesapeake marls and clays rest directly on the granite. Along James River, south of Richmond, notably at Dutch Gap, many outcrops of Potomac sands and standstone can be seen. In Chickahominy valley the dark, sandy clays of the Chesapeake beds are exposed along the creeks and runs. From feather edges on the west, the Potomac, Pamunkey, and Chesapeake beds thicken rapidly down the dip, and at the eastern edge of the county the Potomac may be 300 feet thick, and the Pamunkey and Chesapeake, each 100 feet.

UNDERGROUND WATERS.

Distribution and character.—The occurrence of water in the granite has been described on pages 83-97. The Potomac beds are prevailingly coarse-textured, and contain much water that is available to wells. The Chesapeake sandy clays are dense and the Calvert formation is probably a poor water-bearer within the county limits. The loams and sands of the Columbia contain large supplies of ground water, the depth of the water table below surface depending on the topography. The shallow waters are for the most part soft. Little is known of the quality of the water to be had by deep wells sunk to the Potomac beds.

Springs.—Springs abound. Most are small seeps from beds of sand but a few are of considerable size. One of the largest in the county, known as the Tucker or Bonanza spring, is near Highland Springs on land owned by E. S. Reed. It is situated in a hollow near a small run that flows into Chickahominy River. The water rises from sands and gravel, evidently slope wash, and the geologic relations of the spring are not evident. The water probably comes from near the contact between the Chesapeake and the overlying Columbia sands. The flow, about 28 gallons per minute, is said not to vary during the year. The water is soft, clear, tasteless, and odorless, has been used for drinking purposes by several families at Highland Springs, and has been shipped to Richmond.

Situated a few miles west of Highland Springs, in the Sunderland scarp facing James River, is Como Lithia Spring, the water of which is sold for medicinal and table use. The spring issues from sand beds at the base of the Sunderland formation. The water is clear and sparkling, tasteless and odorless, and contains free carbon dioxide which makes it agreeably light. The following analysis, recalculated to express results in standard form, was furnished by the proprietor of the spring, I. M. Hawks.

Analysis of Como Lithia water.

(Henry Froehling, analyst.)

	Parts per 1,000,000
Total solids	34.
Organic matter	slight trace
Silica (SiO_2)	5.4
Iron (Fe)	0.1
Aluminum (Al)	0.53
Calcium (Ca)	0.86
Magnesium (Mg)	1.1
Sodium (Na)	4.7
Potassium (K)	2.1
Lithium (Li)	0.07
Iodine (I)	0.39
Bromine (Br)	trace
Arsenic (As)	trace
Bicarbonate radicle (HCO_3)	7.9
Sulphate radicle (SO_4)	0.41
Chlorine (Cl)	10.

Free carbon dioxide gas, 31 c. c. per liter.

The spring is in a park with no buildings near, and pollution by contaminated surface waters is improbable. The only improvements at the spring, when inspected, were a bricked pool from which the water was pumped, and a rustic spring house.

Other springs of more or less note in Henrico County are those of E. G. Hopkins, at Glen Allen; of William Dean, on the edge of a slope from the Sunderland plain, 2 miles northeast from Fair Oaks; of A. A. Carlough, half a mile south of Elko; of J. W. Francis, 3½ miles south of Chickahominy; of J. T. Brown, on the Sims place, 3 miles south of Laurel station; and a spring on the Crenshaw tract, 1½ miles east of Laurel. The spring that supplies Barton Heights is mentioned on page 190.

Wells.—While the larger proportion of the dug wells in the rural parts of Henrico County are curbed with wood, there are many, especially near Richmond, that are bricked. Most of the bricked wells are covered and have pumps. There are some driven wells, but outside of Richmond there are few drilled wells.

LOCAL SUPPLIES.

The city of Richmond owns waterworks which distribute James River water. In or near Richmond a number of deep wells have been sunk by hotels and industrial concerns. These wells get water from fissures and joints in the granite, and are of much interest because of the wide variation in yield and quality of water. They are discussed in detail under the heading "Wells in crystalline rocks," on page 83.

A dug well 12 feet in diameter and 112 feet deep at Benjamin Davis' brickyard in the north part of the city is situated just on the edge of the Sunderland plain above Bacon Quarter Branch. It went through Columbia cobble beds and loams and the Chesapeake sandy clays to decomposed granite, but struck nothing that could be identified as Potomac material, and yields little water.

In the Brookland district, which includes residential and manufacturings sections, northwest and north of the city, and had a total population of 10,068 in 1910, water is obtained chiefly from dug wells 10 to 40 feet deep, though there are many drilled wells and some cisterns.

Within a mile of Highland Springs there are over 100 dug wells, which obtain supplies of soft water from sand beds, and range in depth from 20 to 27 feet with an average of about 32 feet.

In Glen Allen dug wells are 20 to 35 feet deep, and most of them strike granite at about 20 feet. The Old Dominion Excelsior Co. has two wells 8 feet square and 22 feet deep that go to the granite, and are connected by a crosscut at the bottom.

Barton Heights, a suburb of Richmond, with a population of 1,388 in 1910, has a public supply from the Mitchell Spring and an adjacent dug well 15 feet in diameter and 44 feet deep, in the scarp back of the spring. The yield reported is about 100 gallons per minute. Some characteristics of the water, which is considered good, are shown by the following sanitary analysis:

Sanitary analysis of water from Mitchell Spring.

(E. C. Levy, analyst.)

	Parts per 1,000,000
Total solids	106.
Loss on ignition	42.
Alkalinity	0.0
Chlorine (Cl)	16.5
Nitrates (NO_3)	0.445
Nitrites (NO_2)	0.0
Iron (Fe)	0.03
Total hardness	32.5

To supplement the supply from this well and spring, the town, in 1909, had a deep well sunk on the east side of the valley of Bacon Quarter Branch. This well, 759 feet deep, yields to a pump 40 gallons a minute of excellent water.

The drilled wells at Barton Heights go through Columbia and Chesapeake beds, getting water from crevices in the granite-gneiss. Most of the drilled wells are from 50 to 150 feet deep, though a few are much deeper.

At Fort Lee, dug wells 15 to 25 feet deep go through red clay into blue marl and then into water-bearing sand. The cost of digging such wells has been $6 or $7. Some of the wells seen were liable to pollution because of insufficient protection at the top.

At Chestnut Hill and Highland Park nearly all householders have dug wells 20 to 40 feet deep, averaging about 30 feet at Highland Park. The water generally is soft.

At Ginter Park most houses are supplied from the deep well described on page 92. Dug wells are 20 to 35 feet deep. One at the Jefferson Laundry yielded water that was too hard for laundry use. Analyses of water from these wells are given in tables 4 and 7.

No account of deep wells in Henrico County would be complete without mention of the boring at Curle's Neck, the 7,000-acre farm of C. H. Senff. This well near James River where the Talbot terrace plain has a maximum elevation of about 30 feet, went through Columbia, Chesapeake, Pamunkey, and Potomac deposits, striking granite at 310 feet. According to Mr. Bedell, superintendent at Curle's Neck, a little sulphur-bearing water was found at 125 and 250 feet, and drilling was continued to 725 feet. In the granite water was struck at various depths, better in quality but less in volume than that above, and at 710 feet the well was temporarily abandoned. After remaining idle for a year, it was tested and the most that could be had was about 10 gallons per minute. As a last resort six or seven charges of dynamite, some 45 pounds in all, were exploded at various depths in the granite, with complete success. Mr. Bedell said that pumping at the rate of 100 gallons per minute continuously for three weeks lowered the water level but a few inches. The water, which is piped to several houses for domestic use and is drunk by 75 to 100 persons, is soft, clear and colorless, without taste or odor.

The depths of dug or driven wells, character of water bed, and quality of water at a number of places in the county are summarized below:

Details of dug wells in Henrico County.

Location	Depth of well *(Feet)*	Water bed	Quality of Water
Elko	15–25	Sand and gravel	Soft and hard
Fair Oaks	18–22	Sand	Soft
Glendale	15–60	....	Soft
Highland Park	20–25	Loam and sand	Soft
Highland Springs	20–40	Sand and gravel	Soft
School	20–50	Rotten granite	Soft
Seven Pines	About 20	Sand	Soft
Varuna Grove	About 30	Sand	Soft

Conclusions.—As the Lafayette and higher Columbia terraces have a thick covering of clay loam it is probable that dug wells, even when houses stand closely, will be satisfactory from a sanitary standpoint, provided that wells are properly protected, and provided they are not sunk close to cesspools or privies. Drilled wells properly cased are, however, preferable. Good water can probably be had by wells drilled to the Potomac beds in the eastern part of the county, but the prospects for flows, even at an elevation of less than 10 feet above tide level, are poor.

ISLE OF WIGHT COUNTY.

General description.—Isle of Wight County, formed in 1634 as one of the original shires of Virginia, lies south of James River and east of Blackwater River. Smithfield, with a population of 1,278 in 1910, is the only incorporated town.

The general slope of the surface is southeast. It varies from flat to gently undulating, though the Columbia terrace plains are somewhat sharply cut along the north and east by creeks flowing to James and Nansemond rivers, of which Pagan Creek is the most important. The creeks in the western and southern parts of the county drain to Blackwater River, have open valleys, and flow sluggishly through cypress swamps. The divide between the James River and Blackwater River drainage runs through the center of the county. Along James River and Pagan Creek the descent from the Wicomico plain to tide level is generally abrupt, there being bluffs along the James 50 to 80 feet high. The slope southwestward from the Blackwater-James divide is gentle, Moonlight having an elevation of 85 feet and the Blackwater bottoms opposite Franklin 30 feet.

Noteworthy features of the topography in the northwest corner of the county, commented on by Rogers,[a] are the wide, poorly drained tracts known as pocosons.

Geology.—The mantle of Columbia loams and sands hides the older beds except along the river and creek valleys. The Potomac and Pamunkey deposits are deeply buried, and the only outcropping Chesapeake formations are the Yorktown and St. Mary's. The sands, clays, and shell marls of the former in places constitute the whole thickness of the bluffs along James River, and at some localities, for instance near Fort Boykin, are beds crowded with marine shells that here and there form hard rock. The thickness of the Yorktown may be 100 feet; of the St. Mary's about 250 feet. The formations are much alike, being differentiated by fossils. The top of the Pamunkey is from 200 to 400 feet below tide level. Nothing positive is known of the Upper Cretaceous beds nor of the Potomac.

UNDERGROUND WATERS.

Distribution and quality.—The Potomac, Pamunkey, and Chesapeake groups contain artesian water. The coarser sands will yield supplies at any point in the county, and along James River will give flows at elevations below 25 to 35 feet. Nothing is known of the quality of the Potomac and Pamunkey waters, but there is every reason to believe that they are potable. The artesian waters in the Chesapeake beds are soft, alkaline, and adapted to domestic use. The shallow water varies in quality from soft in the Columbia sands to hard in the Chesapeake shell marls.

Springs.—There are many springs along tributaries of James and Blackwater rivers, but few of especial importance. Most springs flow from Columbia sands, and a few from the top beds of the Chesapeake.

Near St. Luke's church, built in 1632 (Benn's Church post-office), is a wayside spring of good flow, about 10 gallons per minute, that has been used by wayfarers for nearly 300 years. Its clear, fresh, but hard water flows from shell marls in the Yorktown formation.

Wells.—Dug wells with wood-lining are most widely used. In some places, particularly in the northern part of the county, curbing of 24-inch tile is being substituted for wood. The shallower wells, as a rule, reach Columbia sands and loams; the deeper wells penetrate Chesapeake sand or marl. There are some driven wells scattered in the county, and there are many drilled wells along James River, Everets Creek, and Blackwater River.

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[a] Rogers, W. B., Geology of the Virginias, 1885.

The drilled wells are nearly all of small diameter, 1½ or 2 inches. Depths range from 40 to over 300 feet. Some have but 20 feet or so of casing; others, and especially those drilled recently, are cased to the bottom.

LOCAL SUPPLIES.

Flowing wells along James River.—The town of Smithfield is supplied with water from a creek 3 miles to the west. In the town are a few dug wells which get hard water, and a considerable number of cisterns. A drilled well 300 feet deep found a fine flow of soft alkaline water in the basal Chesapeake (Calvert) beds that are tapped by some wells a few miles farther up the river.

Along James River, above Smithfield, are several flowing wells about 300 feet deep. A part of the flow from one of the wells at a hotel near Day's Point is bottled and sold by the owner as a table and medicinal water. It belongs to the sodic alkaline bicarbonated class, and like waters of this class in the tidewater country, contains little lime in proportion to the total solids in solution. As a table water it is light and pleasant. The mineral content is shown by the following analysis:

Analysis of Day's Point Artesian Lithia water.

(Froehling and Robertson, analysts.)

	Parts per 1,000,000
Total solids	434.
Silica (SiO_2)	12.
Iron (Fe)	0.19
Aluminum (Al)	0.53
Manganese	.008
Calcium (Ca)	2.6
Magnesium (Mg)	1.1
Sodium (Na)	169.
Potassium (K)	6.2
Manganese (Mn)	0.008
Iodine (I)	0.004
Lithium (Li)	0.008
Bromine (Br)	0.36
Arsenic (As)	trace
Carbonate radicle (CO_3)	204.
Sulphate radicle (SO_4)	11.
Phosphate radicle (PO_4)	0.85
Chlorine (Cl)	25.
Carbon dioxide (CO_2) combined	165.
Free carbon dioxide (CO_2) 2.6 cu. in. per liter.	

A well near by, owned by J. P. Tower, is said to penetrate the following succession of beds:

Record of well of J. P. Tower, 3 miles east of Shoal Bay.

Material	Thickness *(Feet)*	Depth *(Feet)*
Soil	1½	1½
Yellow sandy clay	10½	12
Yellow shell marl	18	30
Blue shell marl	140	170
Reddish or "liver-colored" mud	4	174
Blue marl with sandy beds, rocks at base	106	280
Black sand	4	284
Rock	3	287
Blue marl, water	16	303

These wells are on a bluff 30 feet above James River, hence they yield small flows.

The flowing wells near Everets tap local sands high in the St. Mary's formation. The flows are weak, but the water is of good quality—a little harder and less alkaline than that from the deeper Chesapeake (Calvert) beds along James River. The wells were inexpensive, costing only 10 cents per foot for the driller's time, the owner providing the necessary extra labor and the pipe.

Flowing wells along Blackwater River.—On the west side of the county, in the bottom lands along Blackwater River, flowing wells have been drilled from north of Zuni to the south end of the county below Franklin. The wells tap sands lying in the Chesapeake group (St. Mary's formation) about 150 feet below tide level. Most of these wells are of small diameter (2 inches), and are used for household supply or for watering stock. There are several near Zuni. At the plant of the Shaw Lumber Co., at Ivor, elevation 60 feet, a 6-inch well supplies water for a number of houses; because of the elevation the water does not rise to the surface and a pump is used. For details of other wells, see table 5.

Conditions at some of the villages depending chiefly on dug wells are noted in the following summary, compiled from reports of various persons:

Details of dug wells in Isle of Wight County.

Location	Depth of wells *(Feet)*	Water bed	Quality of water
Benn's Church	12–20	Sand	Soft and hard
Bobs	12–40	Sand and marl	Soft and hard
Carrsville	15–24	Sand and clay	Soft
Chuckatuck	18–20	Marl and blue clay	Hard
McClelland	10–30	Sand and marl	Soft and hard
Moonlight	12–15	Sand	Soft
Raynor	10–100	....	Fair
Wells Corner	12–16	Sand	Soft
Windsor	12–18	Clay and sand	Soft, irony
Whitely	10–15	Sand	Soft

Conclusions.—While more care than formerly is now being taken in the location and protection of dug wells, there are many that are liable to pollution. Artesian water of satisfactory quality can be had anywhere in the county at a maximum depth of 300 feet below tide, but to drill with the expectation of getting flows at points higher than 35 feet above sea level will probably prove a waste of effort, except near James River, where carefully cased wells may find water that will rise 40 feet above sea level. Potable water can be found at greater depths, and the Potomac group in particular contains vast supplies. These is nothing to indicate that the Potomac water will not be potable at 1,500 feet below surface, though in the northeast corner of the county these very deep waters are liable to be more mineralized than those obtained from the Chesapeake beds.

JAMES CITY COUNTY.

General description.—James City County, one of the original eight shires of the colony of Virginia, lies north of James River and Chickahominy River, and south of York River. Historically, the county is noteworthy for containing Jamestown, the site of the first permanent settlement of English-speaking people on the American continent, and Williamsburg, the first incorporated city in Virginia. At Williamsburg is William and Mary College, the original charter of which antedates that of Harvard College, making it the oldest chartered institution of learning in the United States.

Situated between York and James rivers, the county has characteristic topography of the western shore type; the Sunderland terrace forms the divide but has been dissected by streams flowing to the rivers on either side. The principal streams are Diascond Creek, a tributary of Chickahominy River; Ware and Taskinash creeks, which empty into York River; and Warwick River, a tributary of York River, which separates the county from Warwick County on the northeast. The greatest elevation of the Sunderland plain is in the northern part of the county between Ware and Diascond creeks, where it is about 130 feet high. Along York River there are only small patches of the Wicomico terrace, but along James River, and particularly along Chickahominy River, there are some wide stretches of it having an altitude of from 50 to 80 feet. The lowest plain is better represented along James River than along York River, and is especially conspicuous in the vicinity of Jamestown Island.

Geology.—The Potomac and Pamunkey beds lie below tide level. The top of the Potomac or Upper Cretaceous is 320 feet below tide level at the west end of the county, and 580 feet at the east end. The top of the Pamunkey is 180 to 380 feet below sea level. Of the Chesapeake formations only the Yorktown and St. Mary's outcrop. Their characteristic dark greenish or bluish sands and sandy clays and included beds of shell marl, weathered to reddish, buff and yellowish tints, are seen at marl pits. The total thickness of the St. Mary's exceeds 200 feet, but is not exposed above tide water within the limits of the county.

UNDERGROUND WATERS.

Distribution and quality.—Ground water, found in the Columbia and Chesapeake formations, is mostly soft, but in places marl beds yield hard; irony water. The water from the Pamunkey and Chesapeake beds has all the characteristics of that from corresponding horizons in adjoining counties. It is beautifully clear and slightly alkaline, but at some places is sulphur-bearing. Though plenty of potable water can undoubtedly be obtained from the Potomac beds little is known of their possibilities.

Springs.—There are a great many springs in the county, but none of commercial importance. They are used to some extent for household supply, but mostly for watering stock. The waters resemble those obtained from shallow wells in being clear and soft when flowing from Columbia sands, and hard or even iron-bearing when issuing from Chesapeake marl beds. Springs of perennial flow are numerous, but flows of more than 10 gallons to the minute are few.

Wells.—Dug wells are the chief source of domestic supply. Some drilled wells have been sunk near Williamsburg and along the river, but the number is not large. The prices for sinking these have varied according to the diameter, etc. A number of 3-inch wells near Jamestown cost about $1 per foot, complete.

LOCAL SUPPLIES.

Williamsburg, with a population of 2,044, had no public water supply system in 1906; the inhabitants relied chiefly on dug wells, though there were some cisterns in the town. The deeper dug wells get hard and irony water from the Chesapeake marls. As the town was without sewers, and the location and surroundings of some wells made their pollution easy, and as water from these wells may travel through the marls a considerable distance without undergoing purification, the quality of the water from the dug wells in the central part of the town was not above suspicion.

The deep wells at William and Mary College, the Eastern State Hospital for the Insane, the ice plant, and the knitting mill, particulars of which are given in table 5, tap coarse greenish sands full of shell fragments near the base of the Chesapeake. The water rises about 35 feet above mean high tide in James River, and as the surface elevation is 60 to 80 feet, pumping is necessary. At William and Mary College, the knitting mill, and the ice plant, deep well pumps are used; at the Eastern State Hospital an air-lift. Two wells supply the hospital; one is 8 inches in diameter; the other, owned by the Marshall estate, is 6 inches. The supply from the first is about 50 gallons per minute and from the second 100 gallons per minute. Thirty-five horse power is required to drive a duplex air compresser (air cylinders 18¼ by 12¼ by 12 inches), which furnishes air under a pressure of 75 pounds per square inch to both wells. The water runs to a reservoir, whence it is forced by a steam pump to an elevated tank. Both wells still throw considerable sand containing fragments of Miocene shells up to several inches in diameter, though the wells have been pumped steadily for over 10 years. The water is used by about 1,000 persons. An analysis made by Dr. W. H. Taylor, State chemist, is given in recalculated form in table 8. An increased supply for the asylum, if needed, can be obtained without great difficulty by deepening the present wells, or by sinking new wells 200 feet or so deeper.

The well at William and Mary College has a deep well pump, geared to a 4-horse power gasoline engine. The yield is about 50 gallons of water per minute. The water is forced to a 30,000-gallon tank on a steel tower 75 feet high. About 200 people used this water in 1906.

The general similarity of the water from the Williamsburg wells is shown by the analyses in table 8. Except for a tendency to foam it works well in a boiler, neither forming scale nor corroding. In the open air it corrodes iron, and tanks on steel towers need to be kept tight to prevent damage to the towers.

Of the wells on York River, one of the most notable is that of W. H. Davis, 235 feet deep, on Taskinash Creek, 2 miles north of Croaker. The water has been sold in small amounts for medicinal and table purposes. An analysis, recalculated from one furnished by the owner, is given in table 8.

A flowing well on Chisholm Creek, 8 miles southwest of Lightfoot, owned by the Powhatan Fish and Gun Club, gets water from a mid-Chesapeake bed at 148 feet.

The flows from recent wells near Jamestown Island deserve particular notice because of their volume and head. The wells (see table 8) get water between 270 and 300 feet below mean high tide in greensands that in places contain pebbles over a half inch in diameter. One of these wells, that of W. H. Ayers, is but 3 inches in diameter yet flows 85 gallons per minute at an elevation of about 15 feet above high tide; the head is 43 feet. This well, at the time it was completed, had perhaps the best flow of any in Tidewater Virginia having the same diameter. The greensand of the water bed contained pebbles of quartz and silicified limestone nearly 1 inch in diameter. Frank Carman, the driller, procured from a nearby well belonging to Chas. Babcock a series of samples, from which and his notes the following log has been compiled:

Record of well of Charles Babcock, 1 mile north of Jamestown.

(Authority, Frank Carman, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Soil and red clay (no sample)	6	6
Reddish sand (no sample); water at 15 feet	10	16
White sand and small gravel; water at 45 feet	39	54
Dark bluish clay (dark greenish, slightly sandy, micaceous clay, with shell fragments)	45	99
Grayish sand	10	109
Shell marl, hard layer of shell rock, drill drops in going through	30	139
Grayish sand	10	149
Light-colored mud, soft at top, tough at bottom	13	162
Very hard gray sand, light stream of water at about 170 feet, would not rise to surface (sample at 173 feet contained glauconite)	16½	178½
Coarse gray sand	2½	181
Coarse black sand (quartz sand full of dark green to black glauconite; sharks tooth at 193 feet; light stream of water at 190 feet, rose to 10 feet of surface)	45	226
Blue mud (dark sandy clay, slightly glauconitic)	25	251
Blue marl, at wells nearby a stiff red clay which choked pipe	3	254
Black sand (coarse quartz sand full of dark glauconite) runs badly and clogs drill pipe, water at 260 feet	26	280
Shell bed in sand	5	285
Sand and shells	4	289
Sand rock	21	310
Sand, with coarse gravel; water-bearing	10	520

Other fine artesian wells in the immediate vicinity are owned by J. H. Franklin and S. W. Grimes. On Jamestown Island, in the rear of the ruins of the old church, a well 6 inches in diameter was sunk in 1905 for the Society for the Preservation of Virginia Antiquities, that owns the ground on which stands the ruins of the church and of Lord Ware's residence. The well flows about 40 gallons per minute at an elevation of 8 feet above high tide. The greensand water bed contains large pebbles.

The water from all the wells near Jamestown Island resembles that from the wells at Williamsburg. A field assay of a sample from the well of W. F. Ayers is given in table 8.

The villages in the county, except Bacon, Jamestown, and Iola, stand on high ground near the line of Chesapeake & Ohio Railway, and get water from dug wells. In places, as near Iola, a spring yields hard water, while a well nearby gives soft water. Such an occurrence of soft water below hard is to be explained by inequalities in the contact between the Chesapeake and the overlying beds. The spring flows from a marl bed in the Chesapeake, while the well on the terrace below does not reach the Chesapeake. The well showed the following section:

Record of well at Iola.

Material	Thickness *(Feet)*	Depth *(Feet)*
Yellow loam and clay	20	20
White sand	2½	22½
Yellow sand	2½	25
Sand, pebbles, and cobbles; water	5	30

The depths of wells, character of water bed, and quality of water at several post villages are shown in the following table:

Details of some dug wells in James City County.

Location	Depth *(Feet)*	Water bed	Quality of water
Bacon	10–15	Sand	Soft and hard
Diascond	15–62	Sand and clay	
Ewell	30–40	Sand and marl	Soft and hard
Iola	10–30	Sand and marl	Soft and hard
Toano	20–40	Sand and gravel	Soft

Conclusions.—Good artesian water can be had nearly everywhere in James City County, but flows can not be expected at elevations greater than 30 feet above tide level. The entire practicability of supplying Williamsburg with soft water free from bacteria is shown by the deep wells already drilled. Larger flows than those now obtained can be had by going to sands 200 feet deeper.

KING AND QUEEN COUNTY.

General description.—King and Queen County, formed from New Kent in 1691, lies north of York and Mattaponi rivers. Walkerton, the largest village, has a population of about 250.

Most of the southern part of the county lies between Mattaponi and Pianketank rivers, but much the larger portion of this part and all the northern part drains to the Mattaponi River, Forge Mill Swamp, and Chesetank Creek being the most important tributaries of the Mattaponi rising within the county. Pianketank River, which rises in Dragon Swamp, is peculiar in having no important tributaries throughout its course. The general relief of the county is like that of much of Tidewater Virginia. The divide between Pianketank and Mattaponi rivers is formed by the undulating Sunderland plain, which is deeply trenched by tributaries of the latter stream. Lower terraces are found along the rivers. The maximum elevations of the Sunderland range between 180 feet at the northwest end of the county, and 100 feet near the southeast end.

Geology.—The greensands of the Nanjemoy formation (Pamunkey) and the sands of the Calvert and Choptank formations (Chesapeake) are exposed along Mattaponi River. The Pamunkey greensands and shells show above low tide level from Beverly Creek to above Walkerton.

The Potomac beds are deeply buried. Of the surficial formation of the Coastal Plain, the Lafayette does not reach as far east as the western end of the county, but all the Columbian formations are present, their clayey and sandy loams forming much the greater proportion of the soils. These formations, the Sunderland especially, are more pebbly toward the western end of the county.

UNDERGROUND WATERS.

Distribution and quality.—The existence of water-bearing sands in the Chesapeake, Pamunkey, and Potomac formations has been proved by artesian wells along Mattaponi River. Most of the wells, at Walkerton and below, get water from Pamunkey greensands, or possibly sands of Matawan age, though in the lack of fossil evidence it is not possible to say that Upper Cretaceous beds extend as far west as King and Queen Courthouse. None of the sands tapped gives flows at over 40 feet above sea level.

All the artesian waters are soft and alkaline from bicarbonate of soda. The iron and lime content are generally low; the proportion of common salt present is remarkably low under the western part of the county, but increases a little toward the east. Most of the flows are not noticeably sulphur-bearing.

The shallow waters vary; most of those in the Sunderland and Wicomico formations are soft. Shallow water in Chesapeake beds is liable to be hard.

Springs.—Springs are numerous, as stream valleys and gullies cut through the Sunderland and later Columbia formations and expose the less permeable beds of the Chesapeake. Many of these springs are of fair size, but none is of commercial importance.

Wells.—Dug wells ranging in depth from 10 to 40 feet are the principal sources of domestic water supply. Driven wells are comparatively few. Along Mattaponi River is a considerable number of drilled wells, 120 to 300 feet deep.

LOCAL SUPPLIES.

At Walkerton dug wells were for many years the sole source of domestic supply. Now there are only three or four dug wells, which are mostly at barns. They get water at depths of 18 to 25 feet in the terrace above Mattaponi River. Water for drinking and household purposes, also for a pickle house, is obtained from artesian wells of which over 20 have been put down. All but one or two get water from Pamunkey sands which lie 200 feet or more below tide level. The deepest well, that of John A. Mitchell, was bored for coal which was supposed to underlie the village. It went down 372 feet but found no coal and no flow below a free one at about 250 feet. The shallowest well, that at the steamboat wharf, is said to be but 180 feet deep, yet it flows a good stream. One well owned by the Mattaponi Pickle Co. gets its flow from the Potomac at a depth variously stated as 330 and 350 feet, but found several flows above the one developed.

No records of the Walkerton wells were kept, but all the beds went through "rock" and found water in black or gray sand below. One well drilled in 1906 flowed a little sand for a few months after it was completed. This sand which came up through a ¾-inch pipe extending to the bottom of the well, 235 feet, consisted of medium fine quartz grains with black and dark green granules of glauconite.

The later wells at Walkerton have casing to the first rock struck or have pipe to the bottom, but the earlier wells were cased only about 20 feet. Many of these wells undoubtedly leak below the casing, have become clogged by sand, and have had their yields reduced by wells at lower elevations, tapping the same bed. Some wells on the terrace, 30 feet above the river, flow very weakly at high tide and at low tide barely drip, though when first completed they flowed strongly. The original head of the deeper Walkerton wells was probably 35 to 40 feet above mean high water.

All the wells yield alkaline water, which at most wells has a faint sulphur odor. The field assay in table 9 shows the softness, the low chlorine content, and the decided alkalinity, characteristics of the flows. This water can be used in a horizontal boiler, but foams badly in a vertical boiler.

Above Walkerton on Mattaponi River is a fine well, drilled at the bottom of a bluff in front of the residence of A. B. Gwathmey. It is but

190 feet deep, but flowed at an elevation of 8 feet, fully 35 gallons per minute. The head is 35 feet, so that while the water will not rise to the level of the ground on which the house stands, 40 feet above the river, it can easily be raised by a ram. The water bed is described as black and green sand below a rock. Samples showed the rock to be a medium-coarse, indurated sand, containing much dark glauconite and many shell fragments; it might be termed a glauconitic sandstone. At a 275-foot well, owned of John N. Ryland, half a mile from the river, the water rises to 17 feet from surface or about 40 feet above tide, and has to be pumped.

Below Walkerton, near the mouth of Mantapike Creek, a 150-foot well, owned by the Mantapike Canning Co., flows 20 gallons per minute of excellent water from basal Chesapeake beds. The actual cost of sinking was about $35.

At King and Queen Courthouse a deep well, owned by the county, formerly flowed, but in 1906 was pumped, the water rising about to the surface. It threw much fine sand which contained grains of glauconite.

Along Mattaponi River below the Courthouse and along York River are many flowing wells. At Chain Ferry are two about 168 feet deep. The flow comes from the same Chesapeake beds that supply most of the many wells at West Point, and the waters are of essentially the same quality, soft, alkaline, and slightly sulphuretted. (See field assay in table 8.)

Near the east end of the county a well near Gressitt, belonging to W. F. Anderson, is cased to rock, and after being in use 11 years flowed 8 gallons per minute at 11 feet above tide. It taps the same beds as the wells at Chain Ferry, and the water is of the same general quality.

A number of villages report the data shown in the following table:

Details of dug wells in King and Queen County.

Location	Depth of well (*Feet*)	Water bed	Quality of water
Biscoe	10–50	Clay, sand and gravel	Soft
Box	30–75		Soft
Carlton's Store	20–60	Sand	Soft
Cologne	20–50	Sand	Soft
Cumnor	20–40	Sand and marl	Soft to hard
Dragonville	10–40		Hard
Edna	15–50	Clay and sand	Soft and hard
Elsom	30–40	Gravel and sand	Slightly hard
Favor	30–50	Marl	Hard
Indian Neck	30–50	Sand	
Little Plymouth	25–40	Sand	Hard to soft
Plainview	20–30	Sand and marl	
Shackelford	14–24	Gravel	Soft to hard
Shanghai	15–25	Sand	Soft
Stevensville	22–45	Marl and sand	Hard

At Edna the deeper wells go through soil, yellow clay, and thin beds of white and yellow sand to about 35 feet, finding water in white sand and small gravel below iron crusts.

At Favor the average section of 35-foot wells shows red and yellow loam, black "fullers earth," "rock," and shell marl; while at Plainview wells go through loam, clay, white sand, and fullers earth, below which is shell marl.

Conclusions.—Artesian water of good quality can be had under the whole of King and Queen County, but flows can not be expected at elevations of over 30 feet above tide. In places where the interference of wells has resulted in diminished yield, more water under higher heads can be had by going deeper. Places on high ground can avail themselves of the soft, germ-free artesian waters by pumps, but at elevations above 50 feet the wells should be of sufficient diameter to permit the use of pump barrels inside the casing.

KING GEORGE COUNTY.

General description.—King George County, formed from Richmond County in 1720, occupies the west end of the Northern Neck, the peninsula between Potomac and Rappahannock rivers. The county contains no large towns and no large villages. Some of the farms are owned by men of wealth who are remodeling the old mansions and installing water supply plants drawing on artesian flows.

Lying near the western edge of the Coastal Plain, and having tidal rivers on two sides, King George County has greater relief than most counties of Tidewater Virginia. As a rule the divide between the rivers is rather narrow, and is much dissected; it comprises portions of the Lafayette and Sunderland plains. The Lafayette plain has an elevation of 220 feet near Boscobel farm. King George Courthouse stands on the Sunderland plain at an elevation of 130 feet.

Geology.—Potomac, Pamunkey, and Chesapeake deposits underlie King George County; the first are not exposed, but the Pamunkey clays and greensands are exposed along Potomac River from the county line to Mathias Point, and along Rappahannock River from 10 miles below Fredericksburg to 4 miles below Port Royal. At the western side of the county the Pamunkey beds rise 125 feet above tide level; at the eastern side their surface is just below tide level. Their total thickness is 200 to 250 feet, and the Potomac-Pamunkey contact dips east 12 to 25 feet to the mile, its depth below tide varying from 50 to 220 feet.

The Calvert formation of the Chesapeake contains much diatomaceous material, especially in the southeast corner of the county near Wilmont Landing on the Rappahannock, where dry fragments of the light-colored diatomaceous clays float when they fall into the river from the conspicuous bluffs.

The Chesapeake sands, clays, and marls are mantled by the buff and yellow Lafayette and Columbia loams with beds of sand, gravel, and cobbles. Boulders 5 feet or more long are found in the lower terraces.

UNDERGROUND WATERS.

Distribution and quality.—The waters in the Columbia sands vary in quality from clear and soft to irony and hard. Although the Potomac sands underlie the whole county, and undoubtedly contain much water, few wells have been sunk to them. The basal sands of the Aquia formation of the Pamunkey contain supplies of soft water. The Chesapeake, as it lies above sea level, contains no sands that yield flows. The shallow Chesapeake waters are generally hard.

Springs.—Because of the dissection of the surface the county contains many springs, mostly of small size. A few are used for domestic supply. None of commercial importance has been reported.

Wells.—Dug wells with wood lining are the main source of domestic supply. Because of imperfect drainage, wells located on the lower and flatter terraces are particularly liable to contamination by surface water, and some of the backyard wells with decayed lining, through which all manner of filth drips at every rain, are a continual invitation to visitations of typhoid fever. Driven wells are much preferable from a sanitary standpoint, and the deep flowing wells are inexpensive in comparison with the security they give.

LOCAL SUPPLIES.

Rappahannock River.—Two miles east of Sealston is a 250-foot flowing well drawing on Potomac beds, owned by John Curtis. It is on a terrace at an elevation of about 35 feet above tide, and flows two-thirds of a gallon per minute. It is noteworthy for showing variations of flow, due to fluctuations of atmospheric pressure, as stated on page 38. The water, used for drinking, is not so soft as the Pamunkey flows, but is of excellent quality. No record was kept of the formations penetrated; the well was driven to 247 feet and drilled below. The flow is from "quicksand."

At or near Port Conway are several flowing wells drawing on the sands at the base of the Pamunkey or on Potomac sands. One supplies water for a canning factory; another at the residence of R. V. Hunter is harnessed to a small ram that supplies the house; and a third at Oakenbrow farm, owned by Dr. J. H. Low, flows only about 2 gallons per minute at the level of the terrace on which it stands, but by a gasoline engine and pump 200 gallons per minute can be forced to a tank at the residence, on a bold headland of the Sunderland terrace, 100 feet above the well.

The character of the material penetrated at Port Conway is indicated by the following generalized section:

Record of well of R. V. Turner, Port Conway.

(Authority, O. D. Hale, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Sand and gravel	12	12
Light and dark clay (blue and lead-colored)	212	224
Sand; water-bearing	8	232

The flows of the Port Conway wells are clear and soft. The water has a slight odor of "sulphur" when fresh from the well. (For field assays see table 8.)

The exact depths of the wells at Wilmont Landing could not be ascertained, but they probably tap the sands near the base of the Pamunkey about 275 feet below sea level.

On the wide terrace along Rappahannock River, near Sealston, is a considerable number of driven wells. From one the following record was reported:

Record of well of Frank Taylor, 2 miles south of Sealston.

Material	Thickness *(Feet)*	Depth *(Feet)*
Red loam	3	3
Red clay	3	6
Fine red sand	6	12
Fine gravel	4	16
Gravel and small rock	2	18
Boulders and cobbles	3	21
Marl, black sand		

This section is said to be characteristic of driven wells in the vicinity.

Potomac River.—Several flowing wells have been drilled along Potomac River from Chatterton east. The waters are from near the base of the Aquia formation of the Pamunkey, or from the Potomac.

A well on Mathias Point is reported to have shown the following section:

Record of well of C. H. Pemberton, Mathias Point.

Material	Thickness (Feet)	Depth (Feet)
Sandy clay	30	30
Black shell marl	35	65
Red clay with shells	56	121
Gravel and sand	20	141
Rock and clay	30	171
Blue clay	30	201
Sandstone and clay; stone at 227 feet, water at 236 feet	35	236

This well has only 16 feet of casing, but a 1-inch pipe runs to the bottom. The water, soft and clear, is used for household purposes. A field assay of a sample is given in table 9.

Near Pluck, Dido, and Vivian are several flowing wells that were drilled at oyster and fish-packing houses. The reported depths range from 175 to 300 feet, but most of the wells probably draw on the Aquia sands. A flowing well near Pluck is but 50 feet deep, and its irony water evidently comes from a bed high up in the Nanjemoy.

At King George Courthouse are 7 or 8 dug wells, 40 to 50 feet deep, that get water from yellowish sands at the base of the Sunderland formation, or at the top of the Chesapeake beds. The quality is fair. Conditions at some of the settlements dependent on dug wells are shown below:

Details of some dug wells in King George County.

Location	Depth (Feet)	Water bed	Quality of water
Edgehill	25–60	Sand	Soft
Hampstead	60–100	Clay and sand	Good in deep wells
Passapatanzy	18–90	Clay, sand and marl	Hard in deep wells
Rollins Fork	40–65	Gravel	Soft
Shiloh	30–50	Sand and marl	Soft

Near Hampstead dug wells penetrate 25 feet of loam and clay, 15 feet of gravel and sand, and find water on the top of the Chesapeake marl. Here and at a number of other points in the county digging into the dark bluish, sandy clay or "marl" of the Chesapeake obtains a scanty supply of water of poor quality for domestic use.

Conclusions.—Good artesian water, soft but alkaline, that will rise 20 to 30 feet above sea level can be had at nearly all places in the county.

KING WILLIAM COUNTY.

General description.—King William County lies between Mattaponi and Pamunkey rivers, extending some 30 miles northeast of the point where they unite to form York River. At the junction of Pamunkey and Mattaponi rivers is the city of West Point, with a population of 1,397 in 1910. The county is rather sparsely inhabited and contains few large villages, some of the larger being Lester Manor, Cohoke, King William, and Aylett.

Topography.—The topography is diversified. The northwestern portion of the county approaches the western edge of the Coastal Plain, and the Lafayette terrace extends into it, but most of the surface is formed by the Sunderland terrace, which is deeply cut by stream valleys. Along both Pamunkey and Mattaponi rivers are expanses of the Wicomico and lower terraces, especially the Wicomico, which contain much good farming land. The elevation of the Lafayette terrace is about 200 feet, while that of the Sunderland is 180 feet in the northwestern part of the county, and 110 feet in the southeastern part. The Wicomico terrace varies in elevation from 50 to 90 feet, and the other lies below 60 feet.

Geology.—Potomac, Pamunkey, and Chesapeake beds underlie the county, but the Potomac beds are not exposed. The top of the Potomac may be 200 feet below tide level on the northwestern boundary of the county, and 400 feet below at West Point.

The greensands of the Aquia and Nanjemoy formations of the Pamunkey group outcrop along the Pamunkey River from the west end of the county to Piping Tree Ferry, where they disappear below the tide level. Above the Pamunkey are Chesapeake sands and clays more or less covered by Lafayette or Columbia gravels, sands, and loams. The base of the Chesapeake is 20 feet above tide level on the Pamunkey near Hanover Courthouse, and 180 feet below at West Point. The base of the Pamunkey group is 150 to 350 feet below. In the Wicomico and Talbot formations of the Columbia, particularly along Pamunkey River, are many large subangular boulders.

UNDERGROUND WATERS.

Distribution and quality.—Ground water that supplies springs and shallow wells is found in the Pamunkey in the western part of the county, in the Chesapeake in the eastern, and in the Lafayette and Columbia terrace materials. Its quality generally is excellent. Artesian waters underlie the whole county. The Chesapeake and Pamunkey groups furnish fine flows in the eastern part of the county. At the western end of the county, where the Chesapeake lies above tide level, water that will rise above tide level can be had from the Potomac, but few wells have been drilled to it.

The Pamunkey and basal Chesapeake waters differ but little, being delightfully soft, and more or less alkaline from the presence of bicarbonate of soda; some are slightly sulphur-bearing.

Springs.—There are many springs in King William County, but few that are of especial note and none of commercial importance.

Wells.—Dug wells are the main source of supply over most of the county; but, except Southampton County, there is no county in Tidewater Virginia having more drilled wells, as a large number have been sunk in the city of West Point. The drilled wells are nearly all of small diameter and the great majority draw on Calvert beds. The flows of properly drilled and cased wells are generally free, but the waters do not rise more than about 35 feet above tide level, hence there are not many wells on the 30 to 50 foot terrace along Pamunkey River above Elsing Green.

LOCAL SUPPLIES.

Aylett, on Mattaponi River, noted in colonial times for its export shipments of corn, has only three dug wells, which are from 20 to 65 feet deep; two sunk over 60 feet obtained scanty supplies of hard water. Several families use the water from a spring just below the terrace on which the village stands.

Two artesian wells on the terrace, 25 feet above the river, get clear, soft water in basal Pamunkey beds at 160 feet below mean high tide. One of these wells, owned by J. C. Fox, was put down at a total cost of but $40. The small flow, one-third of a gallon per minute, is due to the elevation, and possibly also to there being only 20 feet of 2-inch casing in the well, but the flow suffices for domestic purposes and for 20 head of stock, the overflow from a tank at the well being piped to the barn. This well is said to have gone through 20 feet of Columbia loam and sand, some 60 feet of "fullers earth" or fine dark clay, and then through beds of shell marl and rock, five or six "rocks" in all, before finding water in a gray sand. No flows were found above the one used, and the head of this is about 35 feet above mean high tide in the Mattaponi. A complete analysis of a sample of water from this well appears in table 8.

The other well, owned by Dr. J. B. Moore, also has only 20 feet of casing, but a ¾-inch pipe goes to the bottom of the water-bearing sand at 190 feet.

West Point is situated on low land, mostly not over 15 feet high. Along the rivers were formerly open marshes. Owing to the low elevation, a water table near the surface, and a sandy soil, the dug wells or driven pumps which were once the chief source of supply, were particularly liable to pollution, and the city once had a reputation for malaria and typhoid fever. Since the introduction of artesian water there has been a great improvement in public health, and local physicians claim that cases of typhoid fever originating in the city are practically unknown. The total number of drilled wells may be 300. They range in depths from 110 to 360 feet. but all draw on one or more of three water beds: the first at 110 to 120 feet. the second from 160 to 170 feet, and the third from 320 to 340 feet. The first, low in the Chesapeake, yields scant supplies of water having a decided sulphur odor and is now little used. The second, in basal Chesapeake beds, yields water that has a very slight sulphur odor, and to it the great majority of the wells in the city have been drilled. The third, in the Pamunkey, yields water much like that from the second, but it has been tapped by comparatively few wells. The two upper horizons once had strong heads, 15 to 25 feet, but the drilling of many poorly cased wells, and the constant flow from wells near the shore but a few feet above tide, have greatly lowered the heads in both sands, so that wells to the 120-foot sands will not flow at more than 4 or 5 feet above tide, and those to the 165-foot at not over 10 feet. This loss of head through interference has been discussed on page 71. Wells driven to the third flow are put down with care, and are usually cased to the bottom. The head of this flow is about 30 feet above tide.

All the West Point wells feel the rise and fall of the tide, and many flow at high water and do not at low water. The largest well at West Point was put down for the Southern Railway. The record was destroyed by a fire, and detailed records of the many small wells have not been kept.

The following generalized section was given by one of the most careful drillers in the city:

Generalized section at West Point.

(Authority, J. V. Bray, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Loam or marsh mud	10	10
Fullers earth	100	110
White sand and shell, water in shells	11	121
Shells, no sand	5	126
White sand	20	146
Greensand	6	152
Shells, second flow at 160 feet	8	160
Thin bed of reddish clay	1	161
Black sand and gravel, third flow in gravel at 320 feet	160	321

Another record of a well drilled near the post-office is as follows:

Record of well of Wm. Wheeler, West Point.

(Authority, J. Frank Smith, driller.)

Material	Thickness (Feet)	Depth (Feet)
Fullers earth	90	90
Fine white sand, small stream of sulphur water at 112 feet	35	125
Fullers earth	15	140
Shells, with good water at 150 feet	40	180
Black sand with "beautiful gravel" at 316 to 320 feet	140	320
Rocks with sand below	80	400

Artesian water is used at West Point for all domestic purposes and for boiler supply. The large number of wells drilled and their low cost, drillers asking but $50 for a 2-inch well to the second flow, delayed the installation of a public waterworks system. The present system, described on page 78, distributes water from wells tapping the 325-foot flow. The bacterial purity of this water is beyond question, and the quantity obtainable with ordinary care in development should be sufficient for years to come. Field assays of the water from several wells in West Point, and a complete analysis of water from the 165-foot flow, taken from a well at Beech Park, the property of the Southern Railroad Co., are given in tables 8 and 9. The water is notable for the percentage of sulphates.

The water from both the 165-foot and 325-foot wells has a tendency to foam in a boiler, and works best in horizontal boilers. It is, nevertheless, used in vertical marine boilers by tugs and other river craft. With a horizontal boiler it is the custom to blow off some water every few days to prevent the water from becoming too concentrated. The artesian water is much used at the large oyster houses for washing oysters. For this purpose it is most admirably suited, its bacterial purity making it especially desirable for washing shucked oysters.

In or near Lester Manor about 10 drilled wells find flows in fine to coarse Pamunkey sands that contain much dark green glauconite, and many shell fragments, a greensand marl. The following generalized record was furnished from memory:

Record of well of John G. Robins, 3 miles west of Lester Manor.

(Authority, H. E. Shrimp, driller.)

Material	Thickness (Feet)	Depth (Feet)
Clay	60	60
Shell rock	50	110
Fullers earth	90	200

The water bed at this well is a medium quartz sand containing much glauconite.

On Pamunkey River above Lester Manor, wells have been driven at Elsing Green, near Palls, and southeast of Manquin. The driller gave from memory the following record of one of the wells at Elsing Green:

Record of well of Roger Gregory, at Elsing Green.

(Authority, H. E. Shrimp, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Loam and gravel, surface water	10	10
Bluish sandy clay	50	60
Rock, full of fossil shells	30	90
Bluish slightly sandy clay, lighter than clay above, water at bottom	180	270
Soft greenish rock, sandy in places, no shells in it	30	300

A sample from a reported depth of 300 feet was a coarse quartz sand containing much glauconite.

The wells southeast of Manquin may draw on the Potomac flows; one of these, owned by C. B. Chapman, 6 inches in diameter and 237 feet deep, yields 6½ gallons per minute of soft water that is piped to half a dozen places about the farm buildings, and is used in steam boilers (for analysis see table 10). The following record was furnished from memory by Edward Williams:

Record of well of C. B. Chapman, 1 mile south of Manquin.

Material	Thickness *(Feet)*	Depth *(Feet)*
Loam, clay and sand	10	10
Marl and greensand with shells	175	185
Stiff blue clay	40	225
White sand with water	12	237
The water sand is medium coarse and contains flakes of mica.		

Several flowing wells have been drilled at Cohoke to the Pamunkey horizon tapped at Lester Manor. The driller gave the following record of one:

Record of well of J. N. O. Johnson, near Cohoke.

(Authority, H. E. Shimp, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Clay and sand	100	100
Shell rock	52	152
Hard rock	88	240
Quicksand, water		240

The water bed is a medium coarse quartz sand containing much dark green glauconite, and many fragments of shells.

On Mattaponi River opposite Walkerton are wells which draw on horizons tapped at Walkerton, mentioned in the description of King and Queen County.

An attempt was made about 20 years ago to obtain artesian water at King William Courthouse. A well some 350 feet deep found water, but, since the courthouse stands on the Sunderland terrace at an elevation of 135 feet above tide water, no flow was obtained and the well was abandoned. It is stated that the water rose to within 17 or 18 feet of the surface, but since the heads of the flows at Walkerton, a few miles away, are under 40 feet, this seems altogether unlikely.

At some of the villages in King William County which depend on dug wells conditions are summarized as follows:

Details of dug wells in King William County.

Locality	Depth of wells *(Feet)*	Water bed	Quality of water
Beulahville	19–75	....	Hard
Duane	20–40	Sand and gravel	Fair
Enfield	.....	....	....
Lanesville	15–25	Clay and sand	Soft
Mangochick	20–40	....	....
Manquin	20–45	Sand	Soft
Sykron	15–80	Clay and sand	Soft to hard

Conclusions.—Enough wells have been driven to show the entire practicability of getting flows of soft alkaline water at elevations of less than 35 feet over nearly all of the eastern part of King William County. Where wells have been closely driven and have been allowed to flow without restraint, as at West Point, resulting in general loss of head, more abundant flows under higher head of as good water can be had by going deeper.

On high ground, as at King William Courthouse, flows are impossible, but the artesian water can readily be obtained by the use of deep well pumps. At King William a well 450 feet deep will reach the sand supplying the Walkerton wells, but the water from these will not rise to 50 feet of surface.

LANCASTER COUNTY.

General description.—Lancaster County, formed in 1651, lies on the north side of Rappahannock River near its mouth, occupying the southern part of the end of the peninsula between Rappahannock and Potomac rivers. The principal settlements are Irvington and Weems.

The topography, though the greater elevations are less than in counties to the west, shows considerable variety. A high terrace with an undulating surface cut by V-shaped creek valleys extends eastward nearly to Kilmarnock. Lancaster Courthouse stands on it. The maximum elevation in the northwest end of the county is 90 feet. Lower terraces are traceable along Rappahannock River and face Chesapeake Bay. The drainage is mostly to the Rappahannock, the county line on the northeast following the Potomac-Rappahannock divide. Along the bay coast are many tidal inlets and the shoreline is extremely irregular.

Geology.—Though the sandy loams of the Columbia (Pleistocene) formations cover most of the surface, shell beds and sands belonging to the St. Mary's formation of the Chesapeake (Miocene) group are exposed in headlands along Rappahannock River and in creek gullies.

The bottom of the Chesapeake lies 360 feet below tide level at the Richmond County line and nearly 600 feet below at Windmill Point. So far as can be determined from well records the underlying Pamunkey (Eocene) group is about 100 feet thick, its base lying 480 feet to 700 feet below tide. At Windmill Point the top of the Potomac group (Lower Cretaceous) is fully 800 feet below sea level, and crystalline bed rock over 1,000 feet deeper.

UNDERGROUND WATERS.

Distribution and quality.—The Columbia sands and the top beds of the Chesapeake contain much ground water; the quality differs from place to place, here soft, there hard or irony. On low tracts near tidal inlets the ground water is at times brackish.

Artesian waters underlie all the county. The water bed most widely developed is a coarse sand in the Calvert formation, lying about 240 feet below tide at Whealton and 320 feet below at Irvington. The water is alkaline, soft, and sulphur-bearing. This sand either thins out or becomes too clayey to transmit water a few miles east of Irvington, and attempts to get water from it have had little success. Flows have been obtained from Pamunkey sands that lie 500 to 700 feet below sea level, and from Upper Cretaceous deposits. The Pamunkey sands, like the Chesapeake, are less freely water-bearing toward the east end of the county.

Springs.—Below the scarp of the high terrace are springs of the usual Coastal Plain type, few of which are of especial importance.

Wells.—Open dug wells, driven wells, and drilled wells are in use. The driven wells are mostly in the eastern end of the county, the drilled wells along inlets from Rappahannock River and Chesapeake Bay. Depths of dug wells vary from 8 to 50 feet, of driven wells from 10 to 20 feet, and of drilled wells from 100 to over 500 feet. Dug wells in lowlands in the east end of the county are sometimes salted by high tides.

LOCAL SUPPLIES.

At and near Whealton artesian wells, drawing on the Calvert sands at 240 feet below river level, supply drinking water for 200 people, and are claimed to have effected a marked improvement in the general health. The water is used not only for domestic purposes but also at a tomato canning plant and an oyster packing house. The wells are 1½ or 2 inches in diameter. The flow from one well is fed to a ram with 4½-foot fall; the ram elevates enough water 40 feet to keep full a tank in a dwelling house.

The following generalized record is reported:

Record of well of Lewis-Lankford-Tull Co., Whealton.

Material	Thickness *(Feet)*	Depth *(Feet)*
Sand	22	22
Fullers earth or blue clay	192	214
Rocks and sand, rocks one-half to two inches thick; water at 251 feet	42	256

This well has 214 feet of 1½-inch casing; the flow is given as 16 gallons per minute at 8 feet above the river.

O. D. Hale, who has drilled many wells along Rappahannock River, reports the following generalized section:

Generalized section at Whealton.

(Authority, O. D. Hale, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Sand and light clay	65	65
Fullers earth or blue clay	70	135
Rocks and sand, rocks ½ inch to 6 inches thick	45	180
Clay and sand	93	273
Thin rock, with varicolored sand below, water		273

Essentially the same beds are tapped by wells farther down the river near Monaskon.

Near Bertrand, Millenbeck, Weems, and Irvington, perhaps 30 wells from 270 to 580 feet deep, have been drilled for domestic supply and other purposes. The wells at Bertrand, used for washing oysters and for household supply, get water from sands in the Calvert formation about 265 feet below river level. The water is soft and slightly sulphur-bearing. At Millenbeck and Merry Point the wells reach water of about the same quality at 200 to 210 feet. At Weems and Irvington most people get water from dug wells 15 to 35 feet deep. The towns are on a terrace with maximum elevation of about 30 feet. The wells at Weems go through sandy loams and clays and find water, soft, hard, and irony, at 12 to 20 feet, in a thin sand bed that overlies a black mud or clay. A mile west of Weems a dug well found this black clay 20 feet thick. Near the edge of the terrace at Irvington the dug wells, 25 to 35 feet deep, get soft water. About 70 per cent of the wells in the town are bricked, 20 per cent cased with tile, and 10 per cent with wood. The recent wells are nearly all cased with tile. There are many driven wells in the vicinity of the town, most of them about 20 feet deep. Some wells close to the inlets get brackish water.

The drilled wells near Irvington and Weems penetrate two important water sands, one about 330 feet below sea level in the Chesapeake group (Calvert formation), and the other between 200 and 240 feet deeper in the Pamunkey group. The wells driven to the first sand are 1½ inches in diameter and yield small flows, ½ to 2½ gallons per minute, of soft, alkaline water having a decided sulphur odor; the head is low, possibly 10 feet. A 3-inch well at a fish factory at Irvington and another at a country residence across Carters Creek from Weems get excellent water, under a head of about 35 feet above tide, that has no sulphur odor. The well at the fish factory is said to have flowed 58 gallons per minute at an elevation of about 5 feet when first completed; this flow was cut down to about 40 gallons by screening. The water keeps well in vessels and is said to work well enough in a horizontal boiler, but primes in a vertical boiler. The well on the Francis estate had in 1906 a measured flow of about 35 gallons per minute at 6 feet elevation. It is used for general purposes. Field assays of samples from several wells are given in tables 8 and 9.

The following partial analysis of the water at a 330-foot well at the fish factory in Irvington was furnished.

Partial analysis of 330-foot well Carters Creek Fish Guano Co., Irvington.

(Analyst unknown)

	Parts per 1,000,000
Calcium carbonate ($CaCO_3$)	14.0
Calcium sulphate ($CaSO_4$)	4.7
Magnesium carbonate ($MgCO_3$)	8.4
Sodium chloride ($NaCl$)	122.0
Iron oxide (Fe_2O_3)	12.0
Sand, clay, etc.	41.0
Organic matter	68.0

The prices for drilling at Irvington have varied. Some 1½-inch wells to the first flow cost $100; the 3-inch wells to the deeper flow cost about $2 per foot.

Along the river below Irvington, at Whitestone and Westland, two attempts to get flows resulted in failure, the drillers not having had strong enough rigs. Northeast of Irvington on inlets from Chesapeake Bay at Chase's Wharf, Ocran, and near Kilmarnock, are flowing wells that get water 400 to 650 feet below tide level in basal Chesapeake and Pamunkey or Upper Cretaceous beds. The water is used for various purposes. The flow near Kilmarnock, when the well was just completed, was given at 140 gallons per minute through a 3-inch pipe. It supplies a fish factory.

A 660-foot well at Ocran yields an alkaline water that is used for boiler and other purposes at a fish factory. A partial analysis made by the Hartford Steam Boiler Insurance Co., and kindly furnished by Lawford and McKim, of Baltimore, Md., showed each 1,000,000 parts of the water to contain 616 parts of total solids, which included 548 parts of readily soluble matter and 56 parts of silica. The soluble constituents were carbonate of soda (large amount), chloride of soda (considerable), and some sulphate of soda and carbonate and chloride of potash.

The following record of a well on Dimer Creek, probably at Chase's Wharf, has been published by Darton.[a]

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[a] Darton, N. H., Op. cit., p. 176.

Record of well on Dimer Creek.

Material	Thickness *(Feet)*	Depth *(Feet)*
Tough blue clay, with 3-inch sand bed at 170 feet	237	237
Marl with shells and gravel	2	239
Gravel with good supply of water which rises to within 10 feet of surface	2	241
Blue clay	7	248
Rock, underlain by coarse sand mixed with yellow and green clay	2½	250½
No record	2½	153
Clay	132	385
Rather coarse dark sand	3	388
Blue clay	47	435
Sand, fairly coarse, dark buff and white below, 7-gallon flow of water	8	443
Hard rock, very rough, porous	21	464
Coarse sand mixed with clay and mica, 5-gallon flow of water	10½	474½
No record	1½	476
Rock, quite hard	3	479
Blue clay and sand	28½	507½

At Lancaster Courthouse, elevation about 75 feet, an attempt to get a flow some years ago naturally resulted in failure. Dug wells in the vicinity of the Courthouse are 30 to 60 feet deep. The following record of the Courthouse well has been published.[a]

Record of well at Lancaster Courthouse.

Material	Thickness *(Feet)*	Depth *(Feet)*
Bright orange sand, moderately coarse	30	30
Gray sands, moderately coarse with shell fragments	45	75
White and yellow sand intermixed, moderately fine	40	115
Gray sand moderately coarse, some glauconite grains, few shells and thin ferruginous crusts	45	160
Greenish-gray fine sands, mud with some mica and many shell fragments, some glauconite	20	180
Clay, light brownish-gray in color, few sandy streaks, shell fragments	70	250
Clay, light greenish-gray in color	50	300

Some data reported regarding the shallow wells at a number of villages are summarized thus:

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[a] Darton, N. H., Op. cit., p. 176.

Details of shallow wells in Lancaster County.

Location	Depth of well *(Feet)*	Water bed	Quality of water
Alfonso	24–60	....	Soft and hard
Fisherman	8–15	Sand	Brackish
Litwalton	65–70	....	Soft
Millenbeck	10–30	Sand	Poor
Monaskon	10–70	....	Soft and hard
Ottoman	10–60	Shallow, sand; deep, clay and rock	....
Rehoboth Church	10–90	....	Shallow, poor; deep, good
Westland	5–15	Clay and sand	Soft or brackish
Whitestone	8–18	Shallow, sand; deep, clay	Good, soft

Conclusions.—While the mid-Chesapeake sands tapped by the 330-foot wells at Irvington can not be depended on for flows or satisfactory yields farther east, carefully drilled wells can get plenty of water at greater depths even as far east as Windmill Point. There is nothing to show that the water will be too highly mineralized for general use. At points above Irvington where flows from the first sand have been reduced by drilling several wells within a small radius, more water, probably of better quality, can be had by going deeper. Pumping will be required to get water at Lancaster Courthouse from either the Chesapeake sands, about 400 feet below the Courthouse, or the Pamunkey sands 200 feet deeper.

MATHEWS COUNTY.

General description.—Mathews County ranks next above Alexandria County in small area and in density of population. It occupies the peninsula between Pianketank River, Chesapeake and Mobjack bays, and has an extremely irregular outline. There are many villages but no incorporated towns.

The surface of Mathews County is monotonously level, nearly all of it lying within the Talbot plain.[a] From a maximum elevation of about 30 feet near the Gloucester County line the surface gradually slopes east and south to tide level. Along the eastern shores wide stretches of salt marsh fringe the inlets, and the surface slopes so gradually below sea level that heavy easterly gales drive the bay water far inland.

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[a] The writer believes that most of the surface of Mathews County forms part of a terrace that is to be correlated with the Pamlico terrace of North Carolina.

Geology.—In the northwest part of the county gray Chesapeake sands of the St. Mary's formation are here and there exposed in the bluffs along Pianketank River; elsewhere in the county only Columbia or Recent material is visible. Near the west side of the county yellow buff and reddish loams, seen in road cuts and ditches, overlie more sandy beds. Eastward these bright-colored loams grow thinner and disappear, the sands become marly, and along the bay front mud and marl predominate. Near Port Haywood and elsewhere, dark, ill-smelling mud containing tree roots is found at depths of 15 to 25 feet and deeper, and the thickness of Columbia material may be 50 feet.

The bottom of the Chesapeake lies 500 to 600 feet below the surface, and the bottom of the Pamunkey 100 feet deeper. Evidence as to the presence of the Upper Cretaceous is lacking, and nothing is known of the Potomac. Crystalline bed rock is probably 2,000 feet below the surface.

UNDERGROUND WATERS.

Extent and character.—Because of the slight elevation and the nature of the beds the abundant shallow waters in the Columbia sands are not satisfactory at many points in the county, being high-colored, ill-smelling, and even brackish. In the western part of the county near North River dug and driven wells go through a foot of soil, 12½ feet of "yellow" clay, and 4 feet of red clay, finding water in sand below. On ground 20 feet or more high, the water is soft and sweet, while on flats the water is poor. Many of the shallow wells on higher ground go dry in times of drought. Waters from sands at a depth of 100 feet or so vary in quality and in the yield to driven or drilled wells; in places these sands afford plenty of excellent water, in places they supply but little, and this is irony or otherwise objectionable.

Artesian waters under heads sufficient to give surface flows underlie most of the county, but those so far found are not satisfactory. The Chesapeake and Pamunkey, beds which afford such abundant supplies in counties to the west, apparently are too fine-grained under Mathews County to transmit water readily; the waters are under lower head and are more sulphur-bearing and irony.

Springs.—Except in the western part of the county there are few springs large enough to be used for household supply. At Dixie, on Pianketank River, however, several seeps and springs emerge from a bluff of loam and sand. Their total volume is problematical, but two flows, one about 10 feet above the other, caught by wood basins, supply a saw-mill and a tomato canning factory on the shore below. The water is soft, free from iron, and works well in a boiler. Near Hudgins are two springs used for domestic supply and for stock. One owned by N. C. Miller is said to be used by neighbors when their wells go dry.

Wells.—There are many driven wells in the county, conditions favoring their use. In places, however, the fine sands of the water-bed clog pipes and cut the valves of pumps, and dug wells are favored.

LOCAL SUPPLIES.

At Mathews most of the water is from dug wells 8 to 12 feet deep, which, as the surface elevation is about 6 feet, seldom go dry, though wells close to the river get brackish after unusually high tides. Some of these wells are liable to pollution by surface drainage.

Besides the dug and driven wells there are a few cisterns in the village. Several attempts to get artesian water at the Courthouse have not resulted satisfactorily. The last well found water between 100 and 150 feet, and, according to the driller, a stronger flow at 817 feet. The water has a head of only 6 feet, and the yield in September, 1906, was 1 gallon per minute at an elevation of 4 feet. The water has a decided sulphur odor and is little used. The flow is said to have nearly ceased during the summer of 1905. The low head, the temperature, and the quality of the flow, as shown by the field assay in table 11, indicate that much of the water may come from the higher sands of the Chesapeake rather than from Potomac strata.

Near Port Haywood several drilled wells have found at about 100 feet water that is considered soft, and is used for household purposes or for boiler supply. It comes from sands high in the Chesapeake group.

Over much of the county, dug wells fill nearly to the top in wet weather. Where the water is high in iron, ill-smelling or salty, cisterns are much used. On Gwynn's Island, where about 600 people live, wells average only 7 to 9 feet deep.

Particulars regarding dug and driven wells at a number of places are thus summarized:

Details of dug wells in Mathews County.

Location	Depth (Feet)	Water bed	Quality of water
Blakes	8–16	Sand	Soft
Cardinal	8–16	Sand	Shallow wells, soft, brackish: deep wells, hard.
Cobbs Creek	8–10	Sand	Fair
Diggs	7–12	Sand	Soft
Dixie	12–40	Sand and marl	Soft
Grimestead	7–10	Sand	Good
Hudgins	6–10	Sand and clay	Poor
Mathews	7–12	....	Shallow, soft: deep, brackish.
New Point	5–8	Sand	....
North	6–15	Clay and sand	Hard, brackish
Port Haywood	7–25	Mud, shell beds, and sand.	Shallow, soft: deep, hard, and irony.
Susan	6–12	Clay and sand	Shallow, soft; deep, hard.
Tabernacle	6–8	Marl	Good
Williams Wharf	6–12	Shells and sand	Fair

A 70-foot driven well at Port Haywood entered "blue mud and shells" at about 20 feet and struck "soft rock" at 40 feet, but found no water worth mentioning. A driven well 110 feet deep at Fitchett's found water too salty for use. The pipe was pulled back to 50 feet and water was obtained that though a little brackish could be used in a boiler.

Conclusions.—While the Chesapeake beds under eastern Mathews County are apparently fine and clayey, small flows of hard or iron-bearing water may be had from discontinuous sand beds near the top of the group. The prospects of obtaining water of good quality from the Pamunkey beds or below at points east of Mathews Courthouse are doubtful: the odds favor highly mineralized water containing salt, iron and sulphur. Near the Gloucester County line prospects are much better.

MIDDLESEX COUNTY.

General description.—Middlesex County, formed from Lancaster in 1875, lies on the south bank of Rappahannock River, near its mouth, and north of Pianketank River.

The topography is diversified. The Sunderland terrace, elevation 90 to 120 feet, forms the divide between Rappahannock and Pianketank rivers, and is deeply cut by creeks flowing to the Rappahannock. Along this river a bold scarp marks the drop from the Sunderland to the Talbot terrace, and at the east the Wicomico terrace terminates in the scarp that is traceable across the counties south to the North Carolina line. In Middlesex, as in Essex County, to the northwest projecting headlands of the highest terrace give magnificent views of Rappahannock River valley.

Geology.—The Columbia loams, clayey and bright-colored on the high terraces, and of subdued tints along the low terraces, mantle the surface. No beds older than those of the Chesapeake group (Miocene) outcrop anywhere in the county. Shell beds and gray sands of the St. Mary's formation are exposed beneath Columbia sands in low bluffs along Rappahannock River and in the gorges of the larger creeks. The Chesapeake-Pamunkey contact lies at about 300 feet below sea level at the northwest end of the county, and about 600 feet below at Stingray Point. The thickness of the Pamunkey may be 100 to 150 feet. It is probable that marine Cretaceous beds underlie most of the county, but they can not be sharply differentiated on the evidence of such well records as are available. There are no records of wells sunk to Potomac beds, but it is likely that at Urbanna the top of the Potomac group is over 800 feet below sea level.

UNDERGROUND WATERS.

Distribution and quality.—Both the Columbia formations and the topmost beds of the Chesapeake contain ground water. The quality shows the usual variations. The artesian waters in the lower Chesapeake and in the Pamunkey sands are soft, but as a rule more highly mineralized than in Essex County. East of Urbanna the Chesapeake and Pamunkey water beds become gradually finer, the heads of the flows decrease and the mineralization of the water increases. A characteristic of the Chesapeake flows along Rappahannock River is a decided sulphur odor; this soon disappears, but makes the water when fresh from the well offensive to some persons. The deeper flows seem freer from sulphur. The heads of the different flows show local variations, but as far east as Urbanna properly driven wells, where there is no interference, yield waters from basal Chesapeake (Calvert) beds that rise 15 feet above mean high tide; the Pamunkey flows rise 10 feet higher.

Springs.—Along the gorges of the creeks that flow into Rappahannock River, near the foot of the Sunderland scarp, and in Pianketank River valley, there are many springs. Some are of considerable size, flowing 10 gallons or more per minute. A few are used for household supply. None is of commercial importance.

At the head of a small run on the old Fauntleroy place near Saluda, now owned by J. C. Gray, several springs issue from above dark sandy clay, or from marl beds, belonging to the Chesapeake group. Part of the flow of the highest spring supplies a ram that forces water to a tank in the house, 300 feet distant.

Another spring that gushes from a marl bed on a steep slope to Piankatank River, at the residence of J. E. Blakey, 3 miles southwest of Saluda, supplies the house and barn by means of a ram.

Wells.—Dug wells, the chief source of water supply, vary greatly in depth. Most of them have no lining except plank near the bottom; a few are bricked, and a few cased with tile. In places along the lowest terrace there are drilled and driven wells, nearly all of small diameter. Dug wells, bricked, have been completed for 40 cents per foot.

LOCAL SUPPLIES.

Urbanna in 1906 had no public waterworks, but water from a number of artesian wells was given away by the owners to all persons desiring it. A well intended to supply water for a distribution system was drilled to a depth of 590 feet. The record is of interest as the well is one of the few that have been drilled below 500 feet in this part of the Coastal Plain.

Record of waterworks well, Urbanna.

(Authority, R. H. Milligan, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Clay, sand, and gravel	25	25
Marl	175	200
Hard, bluish black clay	20	220
Sand, very light flow of sulphur water, flow not tested	18	238
Rock	1	239
Marl	21	260
Thin rocks, 6 to 8 inches thick, in marl	30	290
White chalky deposit, "neither sand nor clay"	2	292
Marl[a]	108	400
Bluish clay	45	445
White sand, very light flow of sulphur-bearing water	3	448
Coarse gray sand and white gravel	7	455
Hard sand, no water	10	465
Bluish clay	27	492
Sand, water-bearing, flow small but not tested	8	500
Marl	22	522
Hard red clay, "red as paint"	18	540
Softer pink and brownish clay which caved easily	7	547
White loose sand with thin crusts, sand often in little balls easily crushed by fingers, no clay; good flow of water, volume not tested	42	589

[a] Bones and small teeth are reported to have been struck at 400 feet in blue marl.

This well went through both Miocene and Eocene into Upper Cretaceous beds. The quality of the water from the last flow is said to have been excellent. The well, when seen by the writer, was flowing 3 gallons per minute from the sand at 492 feet; the bottom flow had been shut off by the clay beds caving.

A well near by passed through the following strata, according to the driller:

Record of well of G. W. Hurley, Urbanna.

(Authority, R. H. Milligan, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Soil, sand, and clay	25	25
Black mud	100	125
Marl	96	221
Rock	2	223
Coarse sand, flow of sulphur water, volume not tested, possibly 1 gallon per minute at surface	7	230
Soft marl, shelly at top	40	270
Light marl, containing thin layers of rock	15	285
Green marl	5	290
Black sand, not water-bearing, and marl	30	320
Soft blue clay	132	452
Sand, water-bearing; flow not tested	1	453
Rock	1	454
Sand containing bits of lignite, water-bearing; flow at 3 feet above high tide 105 gallons per minute through a 3-inch pipe, head over 30 feet	22	476

The water from this well, together with that from several wells tapping the sulphur water at 225 feet, is used at an ice plate. It is said to work better in a boiler than the water from the 225-foot wells, having less tendency to foam. Like practically all the deep artesian waters of the Virginia mainland, it contains little volatile organic matter, and hence makes excellent ice.

Other flowing wells at Urbanna are said to range in depth from 227 to 290 feet, but probably draw on sands 220 to 235 feet below high tide level. One of the shallowest, that of G. V. Wagenen, was sunk by the owner in less than a day, no rock being encountered. The flow at first was 5 gallons per minute, but had fallen to about 2 gallons in 1906. The water is used at a canning factory. The well of the Urbanna Manufacturing Co. is worthy of note as it is used to supply the cottages of employees, the water being pumped to an elevated tank. The depth of this well could not be ascertained, but the water has a decided sulphur odor and probably comes from the sand at 220 to 235 feet. Field assays of samples from various wells at Urbanna are given in tables 8 and 10.

Above Urbanna, along Rappahannock River, artesian wells have been drilled at Bayport and several other places. The reported depths of the Bayport wells vary from 260 to 300 feet, and the water probably comes from Calvert, basal Chesapeake, sands. The water is used for domestic purposes and for washing oysters. The following generalized section is reported:

Record of well of Bland Brothers, Bayport.

(Authority, O. D. Hale, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Sand	24	24
"Fullers earth" or blue clay	176	200
Alternating strata of rock and sand, rock layers from ½ inch to 10 inches thick, water at 242 feet	48	248

The well has 218 feet of 1½-inch casing. The reported flow is 16 gallons per minute at 7 feet above Rappahannock River.

A driven well at Sandy Bottom, in the east end of the county, found water in deep Columbia beds. The following record is reported:

Record of 78-foot driven well of D. A. Taylor, Sandy Bottom.

(Authority, D. A. Taylor, owner.)

Material	Thickness *(Feet)*	Depth *(Feet)*
No record	30	30
Old wood and shells, blue mud	10	40
White sand	½	40½
Blue mud	32½	73
Gravel, principal water bed	2	75
Blue mud	25	100

Dug wells in Middlesex County, as previously noted, differ greatly in depth and in quality of supplies. Wells on high ground near a terrace edge go deep, usually yield soft water, and seldom if ever, go dry; while wells away from the terrace edge are shallower and more liable to go dry. Many wells go through the Columbia sands and get hard water from the Chesapeake shell beds. Conditions reported from various places in the country are briefly summarized thus:

Details of dug wells in Middlesex County.

Location	Depth *(Feet)*	Water bed	Quality of water
Butylo	40–60	Sand and clay	Good
Church View	20–50	Sand	Fair to good
Dew	15–45	Sand and marl	Hard or irony
Freeshade	12–40	....	Fair
Enoch	10–16	Sand	Hard
Lot	16–35	Sand	Soft to hard
Ruark	10–35	Clay	Shallow, poor; deep, good.
Saluda	40–55	Marl and red clay	Hard and soft
Streets	22–60	Sand	Soft
Urbanna	18–30	Marl	Hard, brackish
Warner	8–32	Red clay	Shallow, poor; deep, good.
Waterview	15–60	Shallow, sand; deep, rocks.	Fair to good
Wilton	15–60	Shallow, sand, deep, rocks.	Fair to good

Conclusions.—Over most of Middlesex County dug wells will remain the chief source of supply because of the cost of developing the artesian sands. Plenty of soft alkaline water can be had from the latter, and if the higher sands at any point yield insufficient flows better yields can be had by going deeper. From none of the sands are heads of more than 35 feet above tide to be expected. Hence wells of sufficient diameter to permit the use of deep well pumps will be required to supply villages on high ground. At Saluda, elevation about 75 feet, flows are impossible; the water will rise to about 40 feet of surface.

NANSEMOND COUNTY.

General description.—Nansemond County lies south of James River near its mouth, and extends from the river to the North Carolina line. The surface of the county is rather even, except for the abrupt descents to creeks and inlets in the northern part of the county, and for the scarp that separates the low ground, in which lies the Dismal Swamp, from the higher ground to the west. The principal stream is Nansemond River, a branch of James River. Jones Creek also flows into the James. Most of the southern part of the county drains to Blackwater River, while the southeastern is included within the Dismal Swamp. Much of the surface is part of the Wicomico plain, at elevations between 60 and 90 feet. The abrupt scarp separating the Wicomico from a lower terrace extends from the North Carolina line northward past Suffolk and Chuckatuck. Lake Drummond.

part of which is in Nansemond County, has an elevation of 22 feet above sea level.

Geology.—Over nearly the whole county the Columbia sands and loams are the only beds that can be seen. North of Suffolk, along the banks of Nansemond River and its branches, the underlying dark greenish or bluish sandy clays of the Chesapeake, often filled with shells, are exposed in many places.

In the eastern portion of the county thick beds of mud and sand, which contain shell marl, have been cut by the canals leading to Lake Drummond. These beds, as shown by their fossils, are of Pleistocene age, and are included in the Columbia group.

Other formations, belonging to the Pamunkey, Upper Cretaceous, and Potomac groups, underlie the Chesapeake but are known only from the records of deep wells. The base of the Chesapeake is 350 to 500 feet below surface, and the base of the Pamunkey lies 450 to 600 feet deep.

UNDERGROUND WATERS.

Extent and distribution.—The water table throughout most of the southern and eastern parts of the county lies very near surface, and in wet weather many wells are full to overflowing. The supplies are generally soft, but because of the liability of pollution are not highly valued. In the northern and western parts of the county where the land lies higher, many wells near the edges of terraces are 30 feet deep or more. The supplies obtained are generally soft. Artesian waters underlie the whole county and attempts to get flows have been made at a number of places, but the only artesian wells in use in 1906 were at Suffolk and Everets. At the former place water is obtained from sandy beds high in the Upper Cretaceous; at the latter place from beds of sand and gravel near the top of the Chesapeake. The Upper Cretaceous water is soft and alkaline, the Chesapeake is less mineralized. Artesian water has been reported found near Chuckatuck, but no particulars as to quality are available.

Springs.—Springs are not especially abundant in Nansemond County, although there are some along the branches of James and Blackwater rivers. None of commercial importance has been reported. A spring of good flow, known as the Buckhorn, one-half mile north of Windsor, yields iron-bearing water.

Wells.—Though there are a considerable number of driven wells in the county, dug wells are far more plentiful. There were in 1906 not over 15 drilled wells in use. The dug wells are usually lined with wood, and, on wide, flat stretches where water is close to surface and surface drainage is defective, are not ideal sources of supply. The driven wells and nearly all the drilled wells are of small diameter. They are much preferable to the dug wells, and when conditions are favorable, that is, where the water lies in soft sand close to surface, driven wells with pitcher pumps attached cost but $5 or $6. The cost of drilled wells depends on their depth and diameter; 2-inch wells near Everets were sunk under contract for $1 per foot to depths of 50 feet or more.

LOCAL SUPPLIES.

Suffolk is supplied with water from Lake Kilby, which in 1906 was distributed by the Portsmouth, Berkeley and Suffolk Water Co. A summary of the supply system is given on page 77.

Various manufacturing concerns use or have used water from dug wells. This is hard and of indifferent quality for boiler supply as it forms scale, and the use of a softening plant or of boiler compounds is necessary. Up to the time of the field work for this report attempts to get artesian water at Suffolk had, with one exception, been failures. This was not because artesian water can not be had but because the wells did not go deep enough. There is a great thickness, probably not less than 300 feet, of Chesapeake sandy clay underlying Suffolk, in which there seem to be no beds that yield water freely. The successful well, that of the Norfolk & Portsmouth Traction Co., is reported to be 803 feet deep. Possibly it might have obtained water enough at a higher level, but the drillers were seeking a flow (an impossible undertaking as the elevation of the well is 63 feet), and continued drilling. The yield is small and the well has given more or less trouble ever since its completion. Apparently the water-bearing sand is fine. The water rises to 33 feet of surface and a deep well pump obtains 11 gallons per minute. The water is said to work well in a boiler if not allowed to become too concentrated, and to be good for ice-making.

The following analysis shows its softness, low lime content, and alkalinity; the chief substance in solution undoubtedly is bicarbonate of soda.

Analysis of water from deep well of Norfolk & Portsmouth Traction Co., Suffolk.

(First Scientific Station for the Art of Brewing, analyst.)

	Parts per 1,000,000
Total residue	596.0
Loss by calcination	20.0
Residue after calcination	576.0
Iron (Fe)	large traces
Lime (CaO)	4.0
Magnesia (MgO)	2.9
Carbonate of soda (Na_2CO_3)	493.0
Chlorine (Cl)	23.0
Nitrate radicle (NO_3)	0.0
Nitrite radicle (NO_2)	0.0
Free ammonia	0.0
Albumenoid ammonia	0.0
Oxygen required	0.02
Total hardness	128.0

Deep wells north of Suffolk.—A group of artesian wells has been sunk near Everets, on Everets Creek. Some are just at the foot of the Wicomico scarp and their heads, as they are of shallow depth, little over 50 feet, are due to the level of the water in the Wicomico plain to the west. In 1906, there were about 8 of these wells, the deepest being down 110 feet. The heads range from 4 to 10 feet above the creek, which is tidal. The following record of one of the wells shows the general character of the beds overlying the water-bearing sand:

Record of well of T. J. Saunders, Everets.

(Authority, T. J. Saunders, owner.)

Material	Thickness (Feet)	Depth (Feet)
Clayey soil on marl	8	8
Blue marl, with few shells	16	24
Black sand, with hard layers or "rocks"	2	26
Blue sand, lighter colored at base	28	54
White sand	30	84

Efforts to find the same flow farther southeast have not been successful; the water-bearing sand probably thins out or becomes clayey, though as the sand dips to the east it is barely possible that the wells did not go deep enough. At Reids Ferry, on Everets Creek, 5 miles southeast of Everets, a 150-foot well sunk for the Nansemond River Brick and Tile Co. did not find water, nor did a well 188 feet deep, a mile east of Chuckatuck, which when the driller stopped work was in black and white sand. A later and deeper well east of Chuckatuck is reported to have found a flow. The general character of the flows at Everets is shown by the field assay in table 7b.

Shallow well conditions near various villages in the county are summarized in the following table, most of the data being obtained from postmasters.

Details of dug wells in Nansemond County.

Location	Depth of well *(Feet)*	Water bed	Quality of water
Cleapur	16–90	Shallow, sand; deep, clay.	Shallow, soft; deep, hard.
Copeland	10–25	Sand	Soft
Hobson	16	Blue mud	Soft
Holland	10–34	Sand	Soft
Savage Crossing	8–30	Shallow, sand; deep, blue marl and "black dirt."	Shallow, poor; deep, good.
Valeria	6–10	Shallow, sand; deep, clay.	Shallow, poor; deep, good.

Conclusions.—There is undoubtedly plenty of artesian water under Nansemond County, but conditions are not so favorable for free flows of good water as in counties to the west. The upper Chesapeake sands are patchy and their limits can be determined only by drilling. The sands lower in the Chesapeake, and those in the Pamunkey, are uncertain water-bearers, but may yield flows with heads of 30 feet above tide through wells carefully drilled and screened. The quality of all the artesian waters deteriorates toward the east and near James River, and in the northeast corner of the county the deep flows may be too mineralized for domestic or industrial purposes.

NEW KENT COUNTY.

General description.—New Kent County, formed in 1654 from York County, lies between Chickahominy and Pamunkey rivers.

The topography is much like that of Charles City County. The highest of the terraces, the Sunderland, has an undulating surface sharply cut by stream valleys. Its greatest elevation is 140 feet. The Wicomico plain is developed along Pamunkey River, as is the lower Talbot, the latter comprising much of the land embraced in the wide meanders of the river. Both Chickahominy and Pamunkey rivers have few tributaries rising in the county; the largest of these, Diascond Creek, empties into the Chickahominy and forms part of the eastern boundary of the county. The divide between Chickahominy and Pamunkey waters crosses the northern part of the county, New Kent Courthouse being on it.

Geology.—Columbia loams mantle the surface. On neither Chickahominy nor Pamunkey rivers are Pamunkey (Eocene) beds exposed, the highest formation visible below being the St. Mary's formation of the Chesapeake (Miocene) group. Its dark, greenish sandy clays are exposed along stream gullies and in bluffs on the south side of Pamunkey and York rivers. The base of the Calvert formation of the Chesapeake group lies above tide level along the western boundary of the county and 180 feet below at Plumpoint. The base of the Pamunkey lies possibly 200 feet below tide water in the western side of the county, and 350 feet below in the east. Whether Upper Cretaceous (Matawan) beds extend as far west as the eastern side of the county is doubtful. Unquestionably, there is a considerable thickness, possibly over 600 feet of Potomac (Lower Cretaceous) beds above bed rock.

UNDERGROUND WATERS.

Distribution and quality.—New Kent County is well watered. Numerous rills and creeks are fed by springs. The ground water in the sands of the Columbia formations is generally abundant and soft. The artesian sands in the Pamunkey group carry plenty of soft water that gives flows up to 26 feet above tide. The Calvert sands at the base of the Chesapeake yield light flows in the eastern part of the county, and, if reports are to be trusted, in the Chickahominy valley as far west as Roxbury. Little is known of the Potomac waters, but they are undoubtedly abundant and generally good.

Springs.—There are many springs in the county, some of which have attracted notice by reason of their size or the quality of their waters. A few are used for domestic supply and one or two are thought to have medicinal value. A spring, or shallow well, 3 miles north of Talleysville, flows about 1 gallon per minute of water that has been sold as Belmont Lithia water. The water comes from marl, and the chief substance in solution is bicarbonate of lime. The appended analysis, furnished by the proprietor, R. E. Richardson of Talleysville, has been recalculated to parts per, 1,000,000.

Analysis of Belmont Lithia water.

(W. H. Taylor, analyst.)

	Parts per 1,000,000
Total solids	221.
Calcium bicarbonate ($CaH_2(CO_3)_2$)	135.
Ferrous bicarbonate ($FeH_2(CO_3)_2$)	15.
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	11.
Manganese bicarbonate ($MnH_2(CO_3)_2$)	0.5
Sodium bicarbonate ($NaHCO_3$)	15.
Lithium bicarbonate ($LiHCO_3$)	0.1
Sodium chloride ($NaCl$)	3.4
Potassium chloride (KCl)	1.2
Ammonium chloride (NH_4Cl)	trace
Potassium sulphate (K_2SO_4)	6.3
Calcium phosphate ($Ca_3(PO_4)_2$)	0.6
Calcium nitrate ($Ca(NO_3)_2$)	trace
Alumina (Al_2O_3)	0.1
Silica (SiO_2)	33.

Sulphuretted hydrogen (H_2S) 0.88 cubic inches per imperial gallon.

Wells.—Dug wells, usually cased with wood, are practically the sole source of water supply on the higher terraces. On the lower terraces are some driven wells. The drilled wells are practically confined to the low ground along Pamunkey and Chickahominy rivers. Nearly all are of small diameter; the depths reported range from 150 to 260 feet.

LOCAL SUPPLIES.

More wells have been driven at Plumpoint than at any other place in the county. They all draw on the Calvert, basal Chesapeake, sands reached by the 165-foot wells at West Point, and yield water of the same quality. Heads are about 20 feet above mean high tide. Above Plumpoint at Whitehouse possibly 10 wells have been driven, all of which draw on the same beds, basal Pamunkey, as the wells at Lester Manor in King William County. The heads range up to 35 feet above mean high tide. The flows, where proper care has been taken in casing, equal the average of Pamunkey wells of equal diameter, being about 5 gallons per minute.

The following generalized record of a well at Whitehouse was published by Darton:[a]

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[a] Darton, N. H., Op. cit., p. 174.

Record of well at Whitehouse.

(Authority, P. H. Sweet, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Soil	15	15
Yellow clay	10	25
Blue fullers earth	40	65
Several thin rock strata, one 18 inches thick	5	70
Soft sand rock	25	95
Red clay	20	115
Greensand marl (?)	50	165
Black sand; water at 210 feet	45	210

Along Chickahominy River wells have been sunk at Providence Forge and near Windsor Shades (Boulevard P. O.). No records were kept of any of these wells, but all obtain water from practically the same horizon in the Pamunkey. At Providence Forge several wells have been drilled; one owned by Col. E. B. Townsend is 216 feet deep, and flows 10 gallons per minute at an elevation of 20 feet above sea level. A field assay of the water is given in table 9. Another well, that of R. E. Richardson, is 215 feet deep; it flowed at first but later had to be pumped. The loss of flow is explained by insufficient casing.

The well at Boulevard is probably the finest in the county. It is 260 feet deep, 4½ inches in diameter, and flows 52 gallons per minute at an elevation of 22 feet above mean high tide. This large flow is probably due not so much to the diameter of the well as to the character of the water bed, which, according to report, was a gravelly sand, whereas at Providence Forge the water bed is finer textured. An analysis of the water from the well at Boulevard appears in table 9. The water is noteworthy for the small proportion of mineral matter it contains.

For the supply of temporary saw-mills dug wells are used. In 1906, there were possibly a dozen such mills in the county, obtaining water from wells 25 to 50 feet deep. Information regarding dug wells at a number of villages is given in the following summary:

Details of dug wells in New Kent County.

Location	Depth of well *(Feet)*	Water bed	Quality of water
Barhamville	12–30	Loam and marl	Shallow, soft; deep, slightly hard.
Dash	18–60	Iron crusts, sand	Hard
Oak	20–60	Shallow, loam; deep, clay.	Soft
Plumpoint	10–15	Sand and gravel	Hard
Providence Forge	10–50	Shallow, loam; deep, marl	Shallow, fair; deep, good.
Tunstall	10–20	Shallow, clay; deep, marl.	Soft and hard

Conclusions.—To properly cased wells the Pamunkey sands will furnish supplies far in excess of present draughts. The Potomac group undoubtedly contains numerous sands that will yield ample flows with heads of 30 feet or more, and recourse can be had to them in case the head of the Pamunkey waters at any place is lowered by the interference of wells drilled too closely or allowed to flow without restraint.

NORFOLK COUNTY.

General description.—Norfolk County, formed in 1697 from Lower Norfolk, extends from the mouth of James River southward to the North Carolina line. In or near Norfolk are many large manufacturing establishments and no less than five railroads have terminals on Elizabeth River.

Almost all the surface of the county forms part of the Talbot terrace, which has a maximum elevation of about 25 feet, hence there are wide expanses of practically level ground and considerable swamp land. Most of the swamp is in the southwestern part of the county, and is part of the great Dismal Swamp of Virginia and North Carolina. The surface of this swamp slopes slightly to the northeast and southeast from the foot of the Wicomico-Talbot scarp which forms its western boundary. Lake Drummond, the only considerable body of fresh water in the State of Virginia, is near the center of this swamp. Its surface is 22 feet above tide level. The principal streams, Elizabeth River and North River, are shallow inlets which head in marshy creeks; Elizabeth River empties into James River and North River into Currituck Sound.

Geology.—The vari-colored loams of the Talbot formation are exposed here and there in shallow road cuts, and except for swamps or marshy tracts and strips of dune sand the Talbot loams form the soils. Below lie soft blue clays and bluish sands containing here and there beds of marine shells of Pleistocene age. The Talbot varies in thickness from 5 feet to perhaps 75 feet; it can not, by available well records, be sharply differentiated from the topmost beds of the Chesapeake group (Miocene). The maximum thickness of the Chesapeake group is not less than 600 feet. The topmost formation of the Chesapeake contains water-bearing beds which have been found by driven or drilled wells of moderate depth. The lower formations of the Chesapeake seem to have few beds coarse enough to convey water readily. The relations of the Chesapeake to the underlying Pamunkey, and the evidence of the deep wells, are discussed elsewhere (see page 97 et seq.).

UNDERGROUND WATERS.

Distribution and quality.—The chief sources of domestic water supply in Norfolk County are the gravels and sands in the Talbot formation, from 5 to 50 feet below surface. The water from the shallow beds at most places is soft, but at many is iron-bearing; and at some, near bodies of salt water, is brackish. The deeper beds give hard water which in some places is iron bearing. The discontinuous sand beds in the upper portion of the Chesapeake yield supplies that are, as a rule, iron-bearing and hard, in fact too highly mineralized for general domestic use.

Springs.—There are in Norfolk County comparatively few springs, but three have been developed on a commercial scale. Two, the White Oak and Landale, front inlets from Mason's Creek, 5 to 5½ miles north of Norfolk. They yield soft, clear water from the Talbot sands. The output has been sold in Norfolk. At the Landale Spring the water issues from the sands just above tide level, and comes from some distance below the surface. The flow varies slightly with stages of the tide. The spring is some distance from the nearest house and the sanitary conditions, when the spring was inspected, were excellent. The following analysis, recalculated to express results in standard form, was furnished by the owner, W. J. Land.

Analysis of Landale Mineral Spring water.

(Henry Froehling, analyst.)

	Parts per 1,000,000
Total solids	87.
Silica (SiO_2)	5.3
Iron (Fe)	0.06
Aluminum (Al)	0.18
Calcium (Ca)	5.8
Magnesium (Mg)	2.5
Sodium (Na)	14.
Potassium (K)	1.3
Lithium (Li)	0.01
Iodine (I)	0.009
Bromine (Br)	trace
Manganese (Mn)	trace
Arsenic (As)	trace
Bicarbonate radicle (HCO_3)	9.2
Sulphate radicle (SO_4)	28.
Nitrate radicle (NO_3)	5.5
Chlorine (Cl)	13.

The White Oak Spring is situated near the Landale, and the water probably comes from the same horizon. The following analysis, which has been recalculated, was furnished by the company putting the water on the market.

Analysis of White Oak Mineral water.
(W. H. Taylor, analyst.)

	Parts per 1,000,000
Silica (SiO_2)	5.4
Iron (Fe)	trace
Calcium (Ca)	21.0
Magnesium (Mg)	2.8
Sodium (Na)	14.0
Potassium (K)	3.6
Bicarbonate radicle (HCO_3)	55.0
Sulphate radicle (SO_4)	29.0
Chlorine (Cl)	15.0

Another spring, owned by Joseph Freitas, on Mason's Creek about 1½ miles due west of the two springs mentioned, has shipped water from time to time.

Wells.—There are probably more driven wells in Norfolk County than in any other county in Virginia. Most of them are shallow, going to the first water-bearing sand. There are many dug wells, most of which are not over 15 feet deep, and a few drilled wells. In some places cisterns are used. The more important deep wells have been mentioned on pages 97 to 116.

LOCAL SUPPLIES.

The city of Norfolk is supplied with water by three distributing systems owned by the city, the Norfolk County Water Co., and the Portsmouth, Berkeley & Suffolk Co. The size, capacity, and general equipment of the different supply system are described on pages 75-81.

In the outskirts of the city are many driven wells. G. B. Todd of Norfolk, who has driven a large number, states that east of Elizabeth River in Norfolk County are two water beds; one at 10 to 15 feet, yields water that is generally soft but is irony in places; and the second at 35 to 100 feet, yields water that is generally harder and is irony at a few places. The following records, furnished by Mr. Todd, show the character of the Talbot beds of the Columbia group.

Record of test-boring, corner of Brooke Avenue and Brush Street, Norfolk.

Material	Thickness *(Feet)*	Depth *(Feet)*
Made ground	4	4
Moist sand	3½	7½
Mud with some sand	7	14½
Mud	6½	21
Yellow clay and mud	7	28
Soft mud	8	36
Fine sand	2	38

This well was driven on made ground, formerly a marsh.

Record of test-boring on Reeves Avenue at river bank, Norfolk.

Material	Thickness (Feet)	Depth (Feet)
Made ground	3½	3½
Gray sand, water-bearing	8½	12
Yellow sand, almost dry	11	23
Blackish mud, very soft, mixed with fine sand	17	40
Solid coarse sand, water-bearing		40

At Lambert Point, a suburb which in 1906 had a separate government, Norfolk County water is used by nine-tenths of the inhabitants. There are, however, numerous cisterns and some driven wells. The latter find two sources of supply; the first water, at 10 to 12 feet, is called poor; deeper water, at 45 feet, is hard, and in places too iron-bearing for domestic use. The Norfolk & Western Railway Co. has used Norfolk County water largely at its yards and terminal on the Point. It once procured water from a system of driven wells 2 miles east of the Point, and subsequently tried a shallow well 30 feet in diameter about a half mile east of its yards. The water from the deep well, mentioned on page 107, is too highly mineralized for boiler use.

At Sewell Point, the site of the Jamestown Exposition, water can be obtained almost anywhere by driving a pipe down 8 or 10 feet. This water is not considered good. The Exposition grounds were supplied by the Norfolk County Co. At Ocean View and on Willoughby Spit, where there are many suburban residences and summer cottages, water is obtained from driven wells. On the Spit the wells are 20 to 25 feet deep. The water is apt to be irony. At Ocean View station wells are about 12 feet deep, and yield better water than along the beach, where they average 18 to 20 feet and yield irony water. A few wells, from 20 to 30 feet deep, strike water in a blue sand below a blue mud. The water has a slight sulphur taste and at some wells is irony. A driller reports that in the vicinity of Ocean View a bed of shells is occasionally struck in the blue sand above the blue mud at a depth of 8 feet. This shell bed is probably of Pleistocene age and part of the Columbia group.

Darton[a] has published records of several borings made by the city of Norfolk in search of shallow water east of the city. The two following are given in slightly modified forms to show the general character of the Columbia materials, and the depth to the main water beds.

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[a] Darton, N. H., Norfolk folio, U. S. Geol. Survey, 1902, p. 4.

Poorhouse tract swamp.

Material	Thickness *(Feet)*	Depth *(Feet)*
Muck	4	5
Firesand	4	9
Sand and clay	23⅔	32⅔
Blue clay	1½	35⅙
Sandy clay	3¼	38 5-12
Sand and clay	7½	45½
Gravel, with water, on sand	6⅓	51⅚

Drummond woods.

Material	Thickness *(Feet)*	Depth *(Feet)*
Sand	3	4
White sand	9	13
Sand and clay	8	21
Clay and sandy clay	9½	30½
Sandy clay	5⅔	36⅙
White sand	2⅙	38⅓
Gravel, with water, on sand	5⅔	44

South of Norfolk, along the South Branch of Elizabeth River, wells have been put down for the boiler supply of mills. Most yield fair water. The E. S. Barnes Co., at its plant on the east bank of the South Branch, 2 miles above the Norfolk Navy Yard, has 10 wells 72 to 86 feet deep. A partial analysis by the Hartford Steam Boiler Co. showed 648 parts of solid matter per 1,000,000, considerable soda, lime, magnesia, chlorides, and sulphates, some silica and potash, and a little iron; the chief substance in solution was sodium chloride, with "traces" of calcium and magnesium sulphates, a rather poor boiler water. Another well, 120 feet deep, yielded somewhat similar water, containing 652 parts of solid matter per 1,000,000. A group of 14 wells, 15 feet deep, at the same plant, yielded water that contained only 164 parts of solid matter per 1,000,000, a good boiler water. In this water the hardness was chiefly temporary, from carbonates of lime and magnesia.

The Pocomoke Guano Co. obtains water from a well 86 feet deep, near Elizabeth River. The following record was furnished by the company:

Record of 86-foot well of the Pocomoke Guano Co., near Elizabeth River.

Material	Thickness *(Feet)*	Depth *(Feet)*
Hard black dirt	3	3
Soft fresh mud, swamp muck	9	12
Blue marl and mud	68	80
Shells, sand and gravel, water-bearing		80

A partial analysis of the water from this well (table 7) shows an unusually high percentage of organic matter.

Another well, that of the Roanoke Railroad & Lumber Co., not far from the two plants previously mentioned, penetrated the following beds, according to the company.

Record of well of Roanoke Railroad & Lumber Co.

Material	Thickness *(Feet)*	Depth *(Feet)*
Surface soil and sand	15	15
Clay, sands at base, water	10	25
Black mud with fine shells, clear water at about 53 feet	28	53
Black mud	10	63

The water is said to be slightly salty and to scale badly in a boiler.

The pumping plant of the Portsmouth, Berkeley & Suffolk Water Co. draws on some 35 6-inch wells, 25 feet deep, about 3 miles south of Berkeley. The wells obtain water from a bed of gray sand below blue mud. The water level of the wells varies considerably. At times it is within 3 feet of surface, but under heavy pumping falls to 17 feet. In 1906, there were no buildings on the tract and the possibility of pollution was remote. The water is said to be slightly hard. A partial analysis furnished by the American Waterworks & Guarantee Co. of Pittsburg, Pa., given in table 7, shows a chlorine content of 17 parts per 1,000,000, about the average in Norfolk County for unpolluted shallow waters at points away from salt creeks or arms of Chesapeake Bay.

At Oaklet, southeast of Norfolk, two water-bearing sands are tapped by the driven wells: The first, 12 to 18 feet below the surface and 8 to 10 feet thick; the second, about 40 feet below the surface, and separated from the first by blue clay. A well driven 124 feet proved a failure, finding no water at that depth. The water from the 40-foot sand is considered more healthful than that from the 15-foot.

The city of Portsmouth is supplied with water from Lake Kilby by the Portsmouth, Berkeley & Suffolk Co. Probably nine-tenths of the inhabitants of Portsmouth use this water, the remainder using driven wells and cisterns.

At the Scottsville yards of the Seaboard Air Line Railway, 1½ miles west of Portsmouth post-office, there are 14 2½-inch wells and 12 4-inch wells, all 60 to 64 feet deep. The elevation of the ground at the wells is about 10 feet. The following record was furnished by the company:

Record of driven wells at yard of Seaboard Air Line Railway, Portsmouth.

Material	Thickness *(Feet)*	Depth *(Feet)*
Fine gray sand	4	4
Very fine gray quicksand with bits of rotten wood and tree trunks at 18 to 20 feet	31	35
Bluish-gray clay from 8 to 10 feet thick	9	44
Very fine light buff sand, water-bearing	6	50
Hard, coarse gravel	10	60

No shell beds were found. The wells have double points, and are driven into the gravel because points in the soft sand corrode quickly. The yields are comparatively free, though the 2½-inch wells are sometimes choked by sand. The draught in 1906 was 200,000 gallons of water daily, which was used for locomotive supply and general purposes. It is considered a good boiler water. Analyses of water from the old and new wells are given in table 7.

The old wells comprise 14 2½-inch and 2 4-inch wells, nearer the creek than the new wells (10 4-inch), and the water consequently contains more sodium chloride. Pumping for several months had slight effect on the quality, as is shown by the analyses.

At Port Norfolk, the Norfolk & Portsmouth Traction Co. has, at a power plant at the corner of Mount Vernon Street and Florida Avenue, a mile south of Elizabeth River, 24 wells, 22 of which are 1½ inch in diameter and 16 feet deep, and two are 2 inches in diameter and 50 feet deep. In 1906, these supplied all the water for the boilers, rated at 950 horsepower, also for washing cars and for fire protection, in all about 55,000 gallons daily. The water is stated to work well in a boiler, forming but little scale. The water from the deep well is said to be harder than that from the shallow wells. A partial analysis furnished by the company, recomputed to standard form, is given in table 7.

Near the Norfolk & Portsmouth Co.'s power house the Air Line Manufacturing Co. had, in 1906, 5 1½-inch wells 38 to 40 feet deep, which supplied water for a boiler capacity of 160 horsepower. The following record is reported:

Record of wells of Air Line Manufacturing Co., Port Norfolk.

Material	Thickness *(Feet)*	Depth *(Feet)*
Clay and sand with water at 8 to 14 feet	14	14
Blue mud	20	34
Sand, water-bearing	4	38

The water was considered hard and a boiler compound was used to prevent scale. A partial analysis, recomputed, is given in table 7.

At the U. S. Naval Hospital in the southern part of the city 4 driven wells, 2½ inches in diameter and 35 feet deep, were sunk 400 feet back from Elizabeth River. The maximum yield obtained by pumping was 50 gallons per minute. The water, which rises to 8 feet of surface, or about tide level, is rather hard and is not used in boilers at the hospital. A partial analysis, furnished by the medical inspector in command, is given in table 7. In the same table appears an analysis of water from a shallow well owned by the Portsmouth Knitting Mills.

In the rural sections of Norfolk County, driven as well as dug wells generally go only to the first water-bearing sand, but some driven wells are 40 to 80 feet deep. The quality of the water varies from place to place, but, except close to tidal inlets, is usually soft. Near the Dismal Swamp, where the water table is almost at the surface, the water is apt to be highly colored and of poor quality.

Data collected regarding shallow wells at a number of places are summarized below:

Details of shallow wells in Norfolk County.

Locality	Depth of well *(Feet)*.	Water bed	Quality of water
Cornland	8–45	Sand	Deep, good
Deep Creek	6–12	Sand	Good
Fentress	10–30	Sand	Shallow, soft, or salty; deep, irony
Gilmerton	8–10	....	Bad
Grassfield	8–14	Sand	Poor to good
Great Bridge	10–15	Sand	Hard
Hickory	10–30	Sand	Soft to hard
Indian Creek	8–12	....	....
Link	8–18	....	Shallow, soft; deep, hard.
Oaklet	12–18	Sand	Shallow, poor; deep, good
Piney Beach	10–15	Clay, sand and gravel.	Brackish
Port Norfolk	10–35	Marl	Not good
Pughs	25–30	Sand	Soft
Sewell's Point	10–50	Sand	Soft, irony, hard
Tanners Creek	10–12	Sand	Soft
West Norfolk	20–30	Sand	Hard

At some places where the shallow water is poor, cisterns are more or less used.

At Great Bridge a dug well struck a shell bed containing "large oyster shells" at 20 feet. Water was found at about 30 feet which quickly filled the well. The owner uses the water for irrigation, and reports pumping 214 gallons per minute without lowering its level.

Conclusions.—Ground water suitable for household and domestic use can be had at many places in Norfolk County at slight cost. Because of the easy pollution of dug wells, unless protected with more than average care, driven wells are to be preferred; water from 25 to 50 feet is less liable to pollution than that from 5 to 20 feet below surface. The best water will be found on dry tracts 10 to 30 feet above sea level, the poorest on lower ground along tidal inlets. Deep artesian water can be had under the whole county; its quality is problematical. Flows of such clear, soft water as are found in counties to the west are not to be expected.

NORTHAMPTON COUNTY.

General description.—Northampton County covers the southern part of the peninsula known as the Eastern Shore. The topographic aspects of the county are much like those of Accomac. Low islands or barrier beaches fringe the eastern coast; behind these are broad, shallow lagoons, mud flats bare at low tide, and wide stretches of salt marsh. On the bay side the shoreline is sharper. The surface elevations apparently lie below 35 feet and the surface is included in the lower Columbia terraces.

Geology.—Reddish buff to yellow clay loam underlies the sandy soil, and is underlain in turn by white and yellowish sands with occasional beds of light clay. The maximum thickness of these beds may be 40 feet. Beneath are the same series of silver-gray or bluish-gray sands, shell beds, and soft, dark clays, that are found in Accomac County, and are regarded as part of the Columbia group. Fewer drilled wells have been sunk in Northampton than in Accomac County, hence information regarding beds of fossil shells is scant, but they evidently occur at varying depths, the least depth reported being 30 feet, near Brighton. There is no evidence available for sharply separating the bottom of the Columbia (Pleistocene) from the top of the Chesapeake (Miocene), but the Columbia may be 100 feet thick. Pliocene beds may be present but have not been recognized.

UNDERGROUND WATERS.

Distribution and quality.—Good water has been found at most places. The depth to the water table, the "first spring," may be 20 feet in places, but usually is decidedly less and probably averages not far from 10 feet. The water table after prolonged wet weather comes to the surface on many flat stretches of land. The water from the deeper sands, the "second and third springs," contains, as a rule, more lime and less iron than that from the "first spring," and, if proper care is taken in its recovery, is practically above suspicion of pollution from surface sources.

Springs.—There are very few springs in the county. One 6 miles east of Chesapeake is reported to flow 1 gallon of clear, soft water per minute.

Wells.—The dug well is still the most widely used source of water supply. Wood casing is being supplanted by tile. Driven wells are becoming more and more popular. It is claimed by some persons that since driven wells came into general use there has been a marked improvement in the public health.

Most of the driven wells get water from the "first spring" and are not over 20 feet deep, but may go down 50 or 60 feet, and some drilled wells go to depths of 100 feet and more. The usual charge for "driving pumps" (putting down 1¼-inch driven wells), is about 30 cents per foot, the point and pump being priced separately. The type of point most used is 3 feet long with 60-mesh gauze screens; gauze as fine as 90-mesh being rarely used.

Wells of 1¼-inch diameter are almost invariably driven. Sometimes the pipe strikes "rocks" so dense that a 75-pound hammer falling 15 feet will not start it, but where conditions are favorable 125 feet of pipe can be driven in 1½ days. Drilled 2-inch wells are put down by the wash process, charges varying from 50 cents to $1 per foot, with point and pump included. These wells often have 6-foot Cook strainers.

LOCAL SUPPLIES.

At Exmore supplies are obtained from the "first spring," wells averaging 10 to 20 feet deep . The tank of the New York, Philadelphia & Norfolk Railroad is supplied with water from a 14-foot dug well, 18 feet in diameter, supplemented by points driven to the "second spring" at 30 to 40 feet. A partial analysis of the water from the 14-foot, 30-foot, and 40-foot wells is given in table 7. The analyses are chiefly interesting for the increase in hardness and in chlorine with depth. An analysis of water from a 12-foot well, made by C. B. Dudley for the Pennsylvania System, showed 8.4 grains of total solid residue per gallon, consisting principally of lime and magnesia sulphate with no carbonate, a slightly corrosive water.

The water in most of the village wells is soft and contains little iron. The pumps and dug wells at Nassawadox and Franktown show wide variations in supplies. At Nassawadox, drillers know 4 "springs" at depths of 8, 18, 28, and 38 feet. Water from the first is considered fairly good, that from the second and third irony, while that from the fourth has a decided sulphur odor. At Franktown, pumps are driven to two water beds, at 20 and at 35 to 40 feet. Both furnish soft water that is not irony, but local physicians prefer water from the deeper bed.

At Eastville, water is found at approximate depths of 10, 30, and 40 feet. Most driven wells go to the 30-foot bed which yields a soft, slightly iron-bearing water. One well driven 105 feet found no water below 33 feet. A well at the Courthouse, much used by the public, is driven 40 feet, and yields good water. (For field assay, see table 7.) The tank of the New York, Philadelphia & Norfolk Railroad has been supplied from a 14-foot dug well that gives a satisfactory boiler water. A partial analysis appears in table 7. Another analysis made by C. B. Dudley showed 11.01 grains per gallon of total solid residue, consisting chiefly of lime and magnesia sulphates, with considerable chlorides.

At Cheriton most pumps get water at 16 or 30 feet; it is said to be medium soft and is more or less iron-bearing, though at some wells it contains very little iron. Water having a decided sulphur odor was found at 63 feet in a well at Huff Brothers' store, and is no longer used. The record of this well is as follows:

Record of well at Cheriton.

(Authority, Huff Brothers, owners.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Soil	1	1
Yellow and gray sand, with water at 14 to 16 feet and 29 to 30 feet	29	30
Blue marsh mud	32	62
Sand and shells: sulphur water	1	63

There are many flowing wells in the county but not nearly so many as in Accomac. Most of them are on the ocean side, several being on Upshur Neck. One of these, on Brownsville Creek, driven by W. M. E. Tilghman, of Nassawadox, for Thomas Upshur, is 127 feet deep, 1¼ inches in diameter, and flowed 1½ gallons per minute at an elevation of 5½ feet above mean high tide. At Oyster, 5 1½-inch wells were drilled some years ago for W. T. Travis. They are said to range in depth from 175 to 225 feet and to strike silver gray sands containing marine shells. The flows are about 1 gallon per minute at 3 feet above mean high water, and about one-third more at high tide than at low. The water has a faint sulphur odor but is excellent and is used for domestic supply and on fishermen's boats. A field assay of water from one well is in table 7.

Cape Charles is the only town in Northampton County having a public supply system. The supply in 1906 came from an open well, 20 feet in diameter and 20 feet deep, and 17 3-inch points, 3 driven to 40 feet, and

14 to less depths. Twelve of these points were owned by the city and 5 by an ice plant. Owing to the steady draught the water table, normally about 8 feet below surface, has been lowered over a considerable area about the points, so that the 12-foot well is ordinarily entirely dry, and contains a few inches of water only after prolonged wet weather. The water from the points which tap the "second spring" in the Talbot sands makes good ice, but forms scale in boilers. In 1906, about three-fourths of the town's population used city water, the remainder using pumps driven to the "first spring."

At the shops of the New York, Philadelphia & Norfolk Railroad are 22 40-foot points and 4 90-foot points directly connected to a steam pump. The log of the deeper wells, situated at 4 feet above mean high tide, is as follows:

Record of well of New York, Philadelphia & Norfolk Railroad, at shops, Cape Charles.

(Authority, Geo. Russell, superintendent motive power, N. Y. P. & N. R. R.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Surface soil	1	1
Buff sandy clay	4	5
Yellow sand, water at 10 feet	10	15
White sand, quicksand with water	25	40
Gravel and pebbles, pebbles yellow, white, red, and black	3	43
Pea-green marl, no shells	10	53
Black mud with rotten wood, no shells	17	70
Shells and sand: good water at 90 feet which rises to 6 feet of surface	25	95

An attempt to get a flow by drilling deeper, made some 20 years ago, proved a failure, no freely water-bearing beds being found to a depth of 300 feet, but the character of the rig used prevented this test from being decisive. In 1910, the railroad had a well sunk over 1,500 feet by a careful driller, but found no strongly water-bearing sand between 40 and 1,520 feet.

The water from the driven wells is used in stationary boilers, also by locomotives and steamboats. It forms a hard scale. At the shops the boilers are run in weekly alternation and thoroughly cleaned when idle. Soda ash caused priming and various boiler compounds tried were too costly for the results obtained. Analyses of water from a 14-foot dug well and from a 90-foot point are given in table 7. It is not impossible, in view of the depression of the water table by pumping and the situation of the wells near the bay, that salt water may gradually work inland and impair the quality of the present supplies at the shops.

The conditions governing the underground occurrence of fresh water on the low islands along the coast have already been discussed (page 117). To get water other than rain water is a matter of considerable importance because of the growing popularity of the islands as resorts. Water from shallow driven pumps is the most available, though this is as a rule high-colored, irony, and, after high tides or dry weather, brackish. Wells sunk 100 to 250 feet may give better supplies, much depending on the location of the island with reference to catchment areas on the mainland.

The conditions on several of these islands are summarized below:

Details of wells on islands of Northampton County.

Island	Deepest well *(Feet)*	Level of water above or below surface *(Feet)*	Yield *(Gal. p. m.)*	Quality	Use
Bone	169	9	3	Irony	**Domestic**
Mockhorn	185	—1½	....	....	**Domestic and stock**
Fisherman's	14	....	....	....	**Abandoned**
Sandy, or Cherrystone.	169 (?)	+1½	10	**Slightly saline**	**Boiler**

No records of the materials passed through have been kept, but water-bearing sands of the Columbia group (Pleistocene) supply the shallow wells, and Chesapeake (Miocene) sands the deep wells.

The well on Sandy Island is of interest on account of the small area and slight elevation (less than 5 feet) of the island, which is nearly covered by a large fish factory. The well supplies 20,000 gallons per day, the flow at 1¼ feet above tide varies from nothing to 10 gallons per minute, but, by pumping, 80 gallons per minute can be obtained. The water, though brackish, is used for drinking and cooking and to supply 7 tubular boilers, rated capacity 800 horsepower. Three fishing steamers owned by the company also use the water. It forms a hard, white scale. A field assay is given in table 8.

The wells on Fisherman's Island were driven to supply the Quarantine Station, the points became clogged by rust, and the wells were abandoned. The Bone Island well was sunk for a club-house and other buildings. The water is used for drinking and other purposes, but contains a rather large percentage of chlorine and is high in iron.

Data regarding wells at other places in the county are summarized below:

a few from shell beds in the Chesapeake group. The great majority are without improvements and are used only for watering stock. From none is water sold.

Wells.—On the higher terraces dug wells are lined with planks at the bottom and at the top, since the loams near surface are sandy. On the lower terraces wells are lined with planks or boards throughout. A small proportion of the wells are lined with brick; very few are cased with tile. On the lower terraces are a few driven wells, and along inlets from Potomac river and Chesapeake bay are many drilled wells. Most of these are of small diameter, under 2 inches, and go only to the first sand that will yield a flow. A few are of larger diameter, 2 to 6 inches, and go down more than 500 feet.

LOCAL SUPPLIES.

At Heathsville, the county seat, all the water used is obtained from dug wells 25 to 45 feet deep; in some wells it is hard.

On Yeocomico and Coan rivers most of the flowing wells get water from Calvert sands at 250 to 320 feet. A field assay of water from the Calvert flow at Coan on Coan River is given in table 8.

The wells on the Great Wicomico are among the most notable in Tidewater Virginia. They range in depth from 590 to nearly 700 feet, and are 2 to 6 inches in diameter. Most of them were drilled by the same contractor, R. H. Milligan, of Crisfield, Md. Through the kindness of Mr. Milligan the following record of a well at Reedville is published:

Record of 698-foot well of J. C. Fisher, Reedville.

(Authority, R. H. Milligan, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Soil, sand, gravel etc	60	60
Sandy clay	20	80
Blue clay	50	130
Dark marl (clay and sand, full of shells)	133	263
Shell rock	8	271
Hard dark marl	101	372
Rock	2	374
Sand, water-bearing: sulphur water, flow not tested	26	400
Soft dark clay	8	408
Dark marl with thin crusts of rock	68	476
Hard rock	4	480
Tough dark clay	210	690
White micaceous sand, contains lignite, water-bearing: flow 18 gallons through a 2-inch pipe at 30 feet above tidewater	8	698

Mr. Milligan also furnished the following notes on the formations penetrated below 670 feet by the well at Fleet Point.

Partial record of well of Fleeton Development Co., Fleeton.

(Authority, R. H. Milligan, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
No record	672	672
Hard white sand containing a little water	20	692
Hard marl, with green clay below	17	709
Sand, water-bearing, flow at surface 15 gallons per minute through 3-inch pipe	1	710
Dark clay or marl	10	720
White sand, water-bearing, flow not tested	1	721
Red clay (a streak not over 1 foot thick and "red as paint" at 725 feet) turning brownish below	19	740
White sand lying in crusts, comes up in balls easily crushed with the fingers, water-bearing; flow 30 gallons per minute through 2-inch pipe	5	745

The red clay and the white sand below it correspond to those struck at Urbanna, in Middlesex County, at 520 to 590 feet.

The water from the deep wells on the Great Wicomico is used for general household purposes, but particularly for boiler supply and for cleaning at the fish factories.

The conditions reported at some places in Northumberland County, where dug and driven wells are the sole sources of supply, are summarized as follows:

Details of wells in Northumberland County.

Location	Depth of well *(Feet)*	Water bed	Quality of water
Blackwells	35–72	Sand and rock	Good
Brown's Store	20–35	Sand	Shallow, salty; deep, good.
Coan	8–80	Sand	Soft to hard
Cowart	10–14	Sand and gravel	Soft
Callao	35–50	Sand	Slightly hard
Fleeton	18	Sand	Soft, brackish
Hyacinth	40–50	Iron crusts and clay.	....
Lottsburg	25–60	Iron crusts and sand.	Soft
Dynhams	8–20	Sand	Soft
Mila	14–50	Sand and marl	....
Reedville	10–15	Sand	Soft
Rainswood	15–25	Sand	Soft
Sampson's Wharf	12–50	....	Soft and hard
Tibitha	7–15	Sand	Good
Wicomico Church	10–80	....	....

Conclusions.—In Northumberland, as in other counties in the Virginia Coastal Plain, the development of ground water by dug wells is not always done with proper care. Though most wells, except those in villages, are not situated dangerously near privies and other sources of pollution, the protection of the wells at surface is usually altogether too slight. An abundant supply of artesian waters that will rise 35 feet above sea level can be had anywhere in the county by properly drilled and cased wells. The development of this water merits more attention than it has received, in spite of the many flowing wells in the county. At Heathville, soft water can be had by drilling 340 feet; it will have to be pumped as it will rise only to within about 40 feet of the surface.

PRINCE GEORGE COUNTY.

General description.—Prince George County, formed in 1702 from Charles City County, lies south of James River and the tidal portion of Appomattox River, east of Petersburg. The most thickly settled portion of the county is near Petersburg, which city is just across the county line in Dinwiddie County.

The county is near the western edge of the Coastal Plain, but, except along James River where the more important creeks, Baileys, Graves, and Chipoak, have cut short valleys, the topography differs from that of counties along the "fall-line" to the north. The headwaters of Blackwater River are only 5 miles from Appomattox River. Blackwater River flows into the Chowan, which empties into Albemarle Sound 150 miles to the southeast. Except near their mouths, the creeks flowing to the James have steep gradients; those flowing to the Blackwater and Nottoway have flatter gradients. The larger streams flow through narrow swamps 30 to 60 feet below an undulating sandy plain. The valley slopes are without steep descents. The highest points in the county are just south of Petersburg and have an elevation of 200 feet, but most of the county is comparatively low, a considerable portion being less than 100 feet above sea level. Terraces are clearly traceable along Appomattox and James rivers, but along the tributaries of Blackwater and Nottoway rivers the terraces grade into each other by slopes; scarps are not prominent. The greater part of the high ground of the county is included in the Sunderland terrace.

Geology.—The oldest visible formation within the county limits is the Patuxent of the Potomac group (Lower Cretaceous). Its characteristic arkosic sandstones and incoherent sands containing pebbles, cobbles, and clay balls, are exposed near Livetenant Run, a tributary of Appomattox

River, in the northwest corner of the county, and in various places near Appomattox River for 4 or 5 miles northeastward. The greensands and shell beds of the Aquia formation of the Pamunkey group (Eocene) outcrop on Livetenant Run near the Petersburg waterworks pumping station and at several places on James River, as in the bluffs at City Point. The Calvert formation of the Chesapeake group (Miocene) containing dark and light diatomaceous clays, and dark and light sandy clays, with shell beds, overlaps both the Pamunkey and Potomac. The base of the Chesapeake is 5 feet above sea level at Coggins Point, but is about 150 feet below at the mouth of Chipoak Creek, 10 miles southeast. Near Petersburg, the base of the Pamunkey is about at sea level, whereas at City Point, 6 miles northeast, it is about 20 feet below, and between is a wide stretch of country where Potomac beds are 50 feet above sea level. The base of the Pamunkey at the mouth of Chipoak Creek is about 300 feet below sea level.

UNDERGROUND WATERS.

Distribution and quality.—An abundance of water is stored in the Columbia sands and the upper beds of the Potomac and Pamunkey groups in the western part of the county, and the upper beds of the Chesapeake in the eastern and southern portions. The quality shows wide differences, but the water generally is soft. Relatively few deep wells have been drilled in the county, and little is known of the quality of the Patuxent and Potomac waters under more than 100 feet of cover.

Springs.—Prince George County contains numerous springs, but none of commercial interest. Some are used for household supply. One of the most noted is at City Point; it really consists of several springs developed by digging along the face of the bluff, and once supplied the hospital of Grant's army. It is now used by several families. The total flow is perhaps 50 gallons per minute. The water is clear, tasteless, and odorless, but, as it comes from shell beds in the Pamunkey, is slightly hard.

At Coggins Point a spring that flows from sand beds near the top of the Chesapeake supplies the residence of David Dunlop. The water is pumped by a gasoline engine from an enclosed masonry basin to an elevated tank, and is distributed thence to the dwelling house and other buildings. The flow is 25 gallons per minute. The water is clear, tasteless, odorless, and low in lime (for field assay see table 6).

Two springs are worthy of note. One, having a flow of 25 gallons per minute, is 2 miles west of Disputanta, the other is at Warwick Church a mile farther west. Both springs flow from surface sands a foot or two above the level of the water in Warwick Swamp. Field assays of the waters are given in table 6. A spring near Garysville has been utilized for household supply by means of a ram.

Wells.—Dug wells that draw on water-bearing sands in the Columbia formations are the chief source of supply in villages and on farms. Most of them are cased with wood, a few with tile; near Petersburg are many deep, bricked wells. The cost of dug wells varies. At City Point the cost of wells 20 to 50 feet deep is $2 per foot for digging and bricking. There are some driven wells and some bored wells. In places ordinary driven wells are unsatisfactory because of fine sand clogging the pipes and cutting pump valves.

LOCAL SUPPLIES.

At Prince George Courthouse only dug wells are used. These yield water that is said to be slightly hard. The lower part of Blandford, a suburb of Petersburg, is supplied with surface water from the Petersburg system. The dug wells on the high ground are 40 to 60 feet deep, and usually get soft water. On the lowland near Appomattox River driven wells get water of varying quality at depths of 20 to 25 feet, from Columbia or Potomac sands and gravels. At City Point, where dug wells 20 to 50 feet deep get hard water, a drilled well 112 feet deep obtains from Potomac gravels plentiful supplies of soft water that is sometimes turbid from clay in the water bed. Samples saved from this well served for the following record:

Record of well of the Misses Epes, City Point.

Material	Thickness *(Feet)*	Depth *(Feet)*
Soil, clay and sand (no sample)	40	40
Fine to coarse quartz sand with a little dark clay and much glauconite	15	55
Quartz sand, glauconitic, and coarse gravel, in light clay	20	75
Fine to coarse white gravel with a little arkosic sand, some glauconite	14	89
Fine gravel in white clay	33	112
Gravel and well-rounded pebbles up to 2 inches in diameter, with a little white clay: water-bearing	....	112

A complete analysis of this water, of interest because of the location of the well, is given in table 11.

At Coggins Point a well 307 feet deep passed through several water-bearing beds between 60 feet and the bottom, but could not get a flow, as the elevation of the well mouth is 63 feet above mean high tide in James River.

At Disputanta, people rely on dug wells about 14 feet deep which get soft water from red, buff and yellow loams of the Columbia group. As the loams stand well, many of the wells are not cased, having only 2 or 3 feet of wood curbing at the top. The average depth of the wells within a mile of Disputanta is 20 feet; the deepest well is 35 feet. In the vicinity of Wall's Store wells on slopes get hard water at 10 to 15 feet in marl, while those on high ground get soft water at 22 to 25 feet in white sand under red clay.

Information regarding dug wells at other points in the county is summarized herewith:

Details of dug wells in Prince George County.

Location	Depth of well *(Feet)*	Water bed	Quality of water
Academy	15-20	Loam and sand	Soft
Brandon	.....	....	....
Burrowsville	15-40	Shallow, sand; deep, marl.	Good and bad
Harrison Grove Corner	32	Sand	Soft
Edlow	20-30	Sand	Soft
Garysville	20-40	Sand	Soft
Templeton	15-40	....	Irony
Spratleyville	30	Sand	Soft
Youngblood's Store	20-35	Sand	Soft

At Spratleyville a bored well near the store went through soil 2 feet; variegated clay, 15 feet; yellow sand, 18 feet; coarse white gravel—water-bearing—1 foot. Near Garysville wells on high ground go through soil, 1 foot; red clay, 10 feet; yellow sand with cobbles, 3 feet; "pipe" clay and red clay, 10 feet; and get water from white sand.

Conclusions.—As the western side of Prince George County is near the edge of the Coastal Plain, there is slight chance of obtaining flowing wells except along James River east of City Point. Flows with heads of 10 to 25 feet above tide can be had from Pamunkey and Potomac beds on low-ground near the river east of Baileys Creek.

At Prince George artesian water can be had from the Potomac beds by pumping; the water will rise to about 35 feet below the level of the Courthouse. At Disputanta, the artesian waters in the Pamunkey and Potomac sands will rise to about 40 feet below the level of the railroad station. Hence there is no chance of getting flows.

PRINCESS ANNE COUNTY.

General description.—Princess Anne County, formed in 1691 from Norfolk County, is bounded on the north by Chesapeake Bay, on the east by the Atlantic Ocean, on the south by the North Carolina line, and on the west by Norfolk County. The only incorporated town in the county is Virginia Beach, a noted resort.

The surface of Princess Anne County is flat and is included in a low terrace. At the northwest, between the eastern branch of Elizabeth River and Lynnhaven Inlet, the surface in places rises 25 feet above mean sea level, but much the greater part of the county has an elevation of less than 20 feet. The highest points are on the sand dunes near Cape Henry, over 75 feet high. The county contains considerable tracts of swamp and marsh land. Shallow lagoons with wide stretches of salt marsh lie back of the barrier beach that extends from a few miles south of Virginia Beach to the North Carolina line. The principal streams are tidal and have marshy shores.

Geology.—No formations older than Columbia beds are exposed. The youngest Columbia formation, as shown by well records, is probably 75 feet thick. It comprises buff loams and light-colored sands, underlain below water level by soft, dark clays, termed marsh mud by well drillers, sands and shell beds.

Below the Pleistocene beds lies the Chesapeake group, the upper part of which shows by well records not less than 250 feet of dark, sandy clay, which contains continuous sand beds and beds of shell marl, but in general is dense and impervious. Pamunkey, Upper Cretaceous, and Potomac beds underlie the Chesapeake in order. Crystalline bed rock is over 2,200 feet below sea level.

UNDERGROUND WATERS.

Distribution and quality.—Water lies near the surface in Princess Anne County, and abundant supplies can be had almost everywhere, but the quality at many places is not satisfactory. The shallow water where the water table is just below the surface is in many places of objectionable color or odor, and is not considered healthful. In some places this water is iron-bearing, and, along tidal inlets and on the barrier beaches, it is brackish. The waters, 15 to 50 feet below surface, are less liable to be polluted and are preferred. In places they are irony or brackish, and as a rule are hard. The discontinuous sands near the top of the Chesapeake group have been little prospected. The quality of the deeper flows, as shown by the well at the Norfolk City Waterworks pumping station, has already been discussed. (See page 110 et seq.)

At their best, the Columbia supplies are soft and clear, and as good drinking water as can be desired. At their worst, they are so highly colored, hard, iron-bearing, and salty as to be unsuited for most purposes.

Springs.—There are few springs in Princess Anne County; one of commercial importance is Diamond Spring, situated on land owned by C. F. Hodgman, a quarter of a mile east of Waterway. The water issues from Talbot sands at the foot of a slight descent to an arm of Lake Lawson, and the flow is said to vary but little during the year. The water has been sold in Norfolk. The following sanitary analysis was furnished by the owner:

Analysis of water from Diamond Spring near Waterway.

(C. F. Chandler, analyst.)

	Parts per 1,000,000
Total solids	36.4
Organic and volatile	12.5
Chlorides	10.5
Chlorides as sodium chloride	17.4
Phosphates	0.0
Nitrogen as nitrates and nitrites	1.55
Permanent hardness, equivalent to $CaCO_3$	13.1

The sanitary surroundings of this spring in 1906 were excellent.

Other springs are those of E. B. Macon and W. B. Strong, 2 miles west of Virginia Beach, which have been used for domestic supply.

Wells.—Driven wells are the principal source of water supply. Many of them are inexpensive, being driven by a maul to the first water-bearing sand and finished with a pitcher pump. The yields vary greatly. Where the ground water is iron-bearing and corrosive the yield is much reduced within a few years by rust clogging the pipe. Wells finished with brass gauze, or slotted brass screens, and good pumps maintain their yield much longer.

Dug wells are used chiefly for stock; because of their easy pollution they are reccommended only for irrigation. Several deep wells have been drilled in the county; particulars of some are given in table 5.

LOCAL SUPPLIES.

The Norfolk County Water Co., which supplies part of the city of Norfolk and several suburban settlements, has its pumping plant on a tract of land containing about 275 acres, some 5 miles northeast of Norfolk, and a mile east of Moore's Bridge. Here the company had driven or dug, previous to December 1, 1906, 36 wells, varying in depth from 30 to 40 feet; all cased with iron. Thirty of the wells are 6 inches in diameter, and 6 are 54 inches. Water normally stands 9 to 17 feet below the surface, which has an elevation of 15 to 25 feet. Below the light-colored Talbot sands are bluish sands containing shells and some dark bluish clay. One well driven 50 feet as a test found no water in these beds. The following average section was given from memory:

Average record of wells of Norfolk County Water Co., Waterway.

Material	Thickness *(Feet)*	Depth *(Feet)*
Soil	1	1
Fine yellowish sand	3½	4½
Yellow and brownish coarser sand with some gravel	10	14½
Fine white sand	2½	17
Medium coarse light yellow sand	16	33
Fine bluish sand with shells, sticky bluish mud below	17	50

Before locating its pumping plant, the company tested several tracts of land north and east of Norfolk, driving possibly 30 wells in all. The present site was selected because of the yield and quality of the water obtainable. An analysis in table 7 shows, according to the company, the average quality of the ground water in the vicinity of its wells.

The pumping plant of the Norfolk City Waterworks is a little more than a mile southeast of the Norfolk County plant. The supply is from shallow ponds, connected by canals. These canals in places went through shell beds lying apparently from 5 to 10 feet below water level. At the pumping station is a deep, artesian well, described on page 110.

At Virginia Beach, which has a population of possibly 5,000 during the height of the bathing season, several attempts to get artesian water have been made. One in 1890 found no water that would rise 10 feet above sea level though the well went down 350 feet. Another well driven some years later at the Princess Anne Hotel obtained water of fair quality at 90 feet. This water did not rise to surface, but to about sea level. In 1906, supplies at the Beach were obtained from shallow wells driven 5 to about 30 feet, estimates of maximum depth varying considerably. The first water is found in sands below buff or yellow clay. The following record was given as a fair average of the materials penetrated:

Well at Virginia Beach.

(Authority, J. L. Walker.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Sandy soil	1	1
Yellowish and reddish clay	10	11
White sand and blue clay in alternating strata. 2 to 4 feet thick	16	27

Most of the wells have hand pumps, some have wind pumps, and a few steam or gasoline pumps.

Some wells yield soft and some yield hard water. Many, near the ocean, yield slightly brackish water. At nearly all wells the water contains some iron, at a few it contains little. Cistern water is largely used for drinking. A field assay of a sample from what was said to be one of the best wells on the beach appears in table 7.

At Cape Henry driven wells, 10 to 20 feet deep, and cisterns are used. Some of the wells yield soft water, but at most the water is highly colored and at some brackish. Along the ocean beach from a few miles south of Virginia Beach to the North Carolina line there is no good well water. Between Lynnhaven and Broad bays clear, soft water is reported at 15 to 25 feet, in sand below red clay and sandy surface soil. Dug and driven wells at other points obtain supplies that vary in quality from place to place. Some conditions reported are here recorded:

Details of wells in Princess Anne County.

Location	Depth of well *(Feet)*	Water bed	Quality of water
Bonney	12–15	Sand	Good
Herbert	25	Sand	Irony
Jacksondale	8–30	Sand	Shallow, soft; deep, hard and irony.
London Bridge	10–20	Sand	Shallow, irony; deep, good.
Lynnhaven	10–18	Sand	Soft, hard, irony
Mapleton	10–15	Shallow, clay and sand; deep, mud.	Shallow, good or brackish; deep, hard and irony.
Nimmo	10–15	Sand	Good
Sigma	20–25	....	Slightly brackish

Conclusions.—Enough driven and drilled wells have been sunk in Princess Anne County to show average prospects. Excellent water can be had near the surface at many points, at other points cistern water or water from ponds or lakes will be found more satisfactory. More attention should be given the location of shallow wells, and the indiscriminate driving of wells 10 to 20 feet deep in the immediate vicinity of privies and cesspools should not be tolerated. Deep drilling in the hope of finding potable water from the basal Chesapeake (Calvert), Pamunkey, Upper Cretaceous, or Potomac sands is inadvisable; in fact, will in all probability prove a waste of effort.

At Virginia Beach the possibility of getting water of satisfactory quality from driven wells in vacant land away from tidal inlets had received little attention up to 1906. The supply of the town must come either from such shallow wells or from ponds.

An adequate supply for the municipal waterworks of Norfolk can be more easily and cheaply obtained from streams than from wells.

PRINCE WILLIAM COUNTY.

General description.—Prince William County, formed in 1730, lies on the west side of Potomac River above the big bend. Only a small part of its area, a strip along the river containing about 80 square miles, lies within the Coastal Plain province.

Lying on the slope from the Piedmont Plain to Potomac River, with differences of altitude of over 300 feet, the Coastal Plain area has been deeply eroded and the topography is rough and broken. Except for a few strips on the lower terraces near the river there is little level ground. Patches of the Lafayette terrace back of Quantico are 300 feet above sea level, but intermediate terraces are traceable with difficulty. The drainage in the Coastal Plain section is in creeks tributary to Potomac River, of which Occoquan Creek, which forms the northern boundary of the county, is the most important.

Geology.—Overlying the crystalline bed rock, which is exposed along the upper courses of the creeks, are the gray arkosic sands and sandstones, and drab and brown clays of the Patuxent formation of the Potomac group (Lower Cretaceous). Except for small scattered patches the Pamunkey (Eocene) greensands and clays have been removed by erosion, and the Chesapeake (Miocene) beds have been entirely removed. The cobble beds, sands, and bright-colored loams of the Columbia formations, and the Lafayette, hide the Potomac beds in many places.

UNDERGROUND WATERS.

The Patuxent formation, as shown by deep wells near the river, contains water-bearing sands that vary in thickness, lateral extent, and yield to wells. At most places one or more sands yield good water freely. Ground waters reached by dug, bored, or driven wells, lie in Columbia, Lafayette, or Potomac sands, at varying depths according to the location of the wells. As a rule the water is soft.

Springs are numerous. Little use is made of most of them and none are now of commercial importance. One, that of J. R. King, a mile north of Dumfries, was a resort of some note 50 years ago.

LOCAL SUPPLIES.

Artesian wells have been sunk at Myron (Cherry Hill), Quantico, and at a point 5 miles north of Quantico. The following record of the well at Myron was obtained from N. H. Darton.

Record of well at Cherry Hill.

(Authority, W. C. Miller, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Top soil	2	2
Sand and gravel	41	43
Sandy clay	47	90
Yellow sand and gravel with water	22	112
No record	15	127
Yellow sand and gravel, some water	6	133
Blue clay mixed with sand, some water	8	141
Blue and brown clay	16	157
Blue sandy clay	8	165
No record	2	167
Fine sand with water	18	185
Blue clay, mixed with a little sand	53	238
Coarse sand with gravel, plenty of water	14	252
Blue clay and sand with rock (?) at 257 feet	5	257

The well yielded 50 to 60 gallons per minute during an 8-hour pumping test.

The water is soft and slightly iron-bearing, a yield by pumping of about 320 gallons per minute through a 4-inch pipe is reported.

The well at Quantico is 210 feet deep. Darton[a] has published this record:

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[a] Darton, N. H., Op. cit., 1896, p. 177.

Record of well at Quantico.

Material	Thickness *(Feet)*	Depth *(Feet)*
White clay	22	22
Fine gravel	6	28
Red clay	25	53
Fine red sand	5	58
Very hard blue clay	28	86
Fine sand	3	89
Dark clay	35	124
Coarse dark sand	3	127
Light-colored clay	78	205
Very coarse sand and water	5	210

This well, 4 inches in diameter, flowed 30 gallons per minute at 10 feet above the river. The head is said to have been 22 feet. The water is used by a number of families in the village.

The well 5 miles north of Quantico was sunk for the projected town of Barrow, and is little used. Water was struck in a bed of sand, or sandstone, at 143 feet. The following record has been published:[a]

Record of well at Barrow.

Material	Thickness *(Feet)*	Depth *(Feet)*
Clay and marl	10	10
Gravel	10	20
Clay	10	30
Sandstone	14	44
Coarse sandstone, water-bearing	1	45
Sandstone	12	57
Bluish sandy clay	1	58
Brown clay	15	73
Bluish sandy clay and fine sand	40	113
Sandstone, large supply of water	30	143
Yellow clay	4	147
Sand with pebbles	13	160
Yellow clay	5	165
Brown clay	30	195

Some reported depths of dug wells and the supplies obtained are as follows:

Details of dug wells in Prince William County.

Location	Depth of wells *(Feet)*	Water bed	Quality of water
Agnewville	25–65	Gravel	Soft to irony
Dumfries	20–80	Shallow, iron crusts; deep, clay	Soft, hard, irony
Neabsco	20–30	Sand	Soft

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[a] Darton, N. H., Op. cit., 1896, p. 177.

RICHMOND COUNTY.

General description.—Richmond County, formed in 1692 from old Rappahannock County, is in the Northern Neck, the peninsula between Potomac and Rappahannock rivers. The more important creeks, Monatico and Totuskey, drain into the Rappahannock. The topography resembles that of many counties north of James River. The creeks head in sharply cut valleys and are tidal and bordered with salt marshes along their lower courses. The maximum altitude of the Sunderland plain is about 150 feet, near Farmers Fork, and 100 feet near Downings.

Geology.—The loams of the Columbia formations are exposed in many road cuts. The dark, clayey sands of the St. Mary's formation of the Chesapeake group (Miocene) outcrop at numerous points along Rappahannock River and its tributary creeks. Pamunkey (Eocene) beds are not exposed, the base of the Chesapeake lying about 50 feet below tide in the northwestern corner of the county, and 300 feet below near Simonson in the southeastern part. Upper Cretaceous beds probably underlie the Pamunkey and are in turn underlain by Potomac. The bottom of the Pamunkey is probably 300 feet below tide at Carter's Wharf, and 450 feet below at Simonson. Bed rock lies fully 1,000 feet deep.

UNDERGROUND WATERS.

Distribution and quality.—The sands of the Columbia formations and the highest Chesapeake beds contain ground water that varies in quality from soft and clear to hard and irony. Near the middle of the Chesapeake in the Choptank formation and toward its base in the Calvert formation are coarse sands that yield artesian water. Other sands lie in the Nanjemoy formation of the Pamunkey. Heads vary from 20 to 35 feet above tide. Chesapeake and Pamunkey waters are soft and limpid, but the former have as a rule a slight odor of sulphur. The Chesapeake waters, as in Essex County across the Rappahannock, are less alkaline and contain more lime than farther east. At a number of places the substitution of artesian for shallow well water is said to have resulted in a marked improvement of the public health.

Springs.—Richmond County abounds in springs, but little use is made of them, except by stock. The springs are of small volume, seeps rather than bold flows, relatively few exceeding 5 gallons per minute. One owned by A. J. Snyder, near Blantyre, flows about 5 gallons per minute of soft water from iron crusts at the base of the Sunderland formation. There is no spring in the county from which shipments of water are reported, or is a resort.

Wells.—Dug wells are almost the sole source of supply on high ground. Many are cased with wood from top to bottom. At some of the old churches and at old manor houses are bricked wells. Many of the shallow wells fail in prolonged droughts. Along Rappahannock River and tributary creeks are a considerable number of drilled wells, practically all of small diameter. The contract price for sinking about 275 feet ranges from $50 to $75. The actual labor cost of sinking, if everything goes nicely and no hard beds or "rocks" are encountered, may be $25.

LOCAL SUPPLIES.

At Warsaw, on the Sunderland plain, water is obtained from dug wells 35 to 50 feet deep, of which there are about 30. The following is an average section of the beds penetrated:

General section at Warsaw.

Material	Thickness *(Feet)*	Depth *(Feet)*
Soil	5	5
Red clay	17	22
White sand	14	36
Red sand and clay	3	39
Rock, iron crusts	2	41
Fullers earth, dark blue clay	....	....

The white sand bed halfway down gives much trouble to wells cased with plank in the usual way. The average life of the plank, as it is above water level, is but 6 or 7 years, and replacing the casing when decayed is more or less troublesome.

Along Rappahannock River not less than 50 artesian wells have been driven, there being at least 17 at Sharp's Wharf alone. Depths vary from 165 to 366 feet, but most of the wells draw on sands in the Calvert formation 160 to 300 feet below tide. Summarized information is given in table 5.

The following record of a well at Naylor's Wharf is given by Darton[a]:

Record of 366-foot well at Naylor's Wharf.

Material	Thickness *(Feet)*	Depth *(Feet)*
Surface deposits	20	20
Fullers earth	100	120
Marl	15	135
Rock strata, 1 to 15 feet apart, containing water	20	155
Black sand	15	170
Blue fullers earth	90	260
Dark orange-colored loam	15	275
Black sand, full of water, which rises to 35 feet above tide	50	325
Blue fullers earth, underlain by a soft rock layer, with water that rises to 45 feet above tide	60	385

[a] Darton, N. H., Op. cit., p. 175.

This well is used for domestic supply and by a canning factory. The quality of the water, which rose from a black sand in the Aquia formation, is shown by the field assay in table 9.

At Sharp's Wharf, one of the most important oyster-shipping points on Rappahannock River, most of the flowing wells go about 240 feet below tide and get water in the Calvert formation, from the same sand beds that are tapped by the wells at Bowler's Wharf on the opposite shore of the Rappahannock. A few go 360 feet to the Nanjemoy, and at least one reaches an Upper Cretaceous (?) sand at 440 feet. The head of the 240-foot wells was originally 24 feet, that of the 320-foot wells is about 30 feet above tide. The water is used for removing the mud from oysters as they are brought from the beds, and for washing shucked oysters. The flows are also utilized to keep oysters from freezing in winter, a pile of several hundred bushels being kept through the sharpest frosts without injury by allowing the water, which has a temperature of 63° F., to flow over them.

At one of the wells near Wellford's Wharf, which draws on Choptank sands, the following beds were penetrated:

Record of 165-foot well of Frank Garland at Wellford's Wharf.

(Authority, Frank Garland, owner.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Sand	5	5
Blue mud or "marl"	30	35
Gravelly sand	50	85
Thin strata of rock	55	140
Sand and rock, with hard rock stratum at 163½ feet; water in shell rock at 156 feet	25	165

This well, at an elevation of 6 feet, flows 24 gallons per minute. The head is about 22 feet above mean high tide, and is a foot lower at ebb than at flood tide.

Near Whealton are several wells that tap deeper sands in the Calvert formation.

Near the bridge across Totuskey Creek east of Warsaw, several flowing wells draw on Calvert sands at about 180 feet. The water is used for domestic purposes, in saw-mill boilers, and at a canning factory. It is called a fairly satisfactory boiler water though having a tendency to foam. Field assays are given in table 8.

The following record of a well higher up Totuskey Creek is of interest from the occurrence of a sand yielding artesian water at a depth of only

65 feet. This sand, which was found also in a dug well, is probably of limited extent.

Record of well of W. E. Garland, near head of Totuskey Creek, 5 miles east of Warsaw.

Material	Thickness (Feet)	Depth (Feet)
Surface wash	8	8
Blue marl, water at 65 feet	157	165
Rock	2	167
Blue marl	17	184
Rock	3	187
Sand (composed of medium quartz grains with much dark green to black glauconite): water, head at 30 feet	1	188

The flow is 16 gallons per minute through a 1½-inch pipe at 8 feet above river. This well was put down by the owner in less than a day. The water is used for household purposes. The overflow, received in a cement basin protected by a small building, prevents viands from freezing in winter and keeps them cool in summer.

Data collected at various places in the county regarding dug wells are given below:

Details of dug wells in Richmond County.

Location	Depth of well (Feet)	Water bed	Quality of water
Blantyre	20–50	Clay or sand	Hard
Carters Wharf	16–50	Loam and sand	Soft
Downings	35–45	....	....
Farmers Fork	25–60	....	Good
Farham	.....	Sand or clay	Soft to hard
Haynesville	12–60	....	Shallow, soft; deep, hard.
Ivondale	12–65	....	Shallow, hard to soft; deep, hard.
Newland	18–45	Clay	Soft
Sharps	18–20	Clay and sand	Hard
Wellford	15–22	Sand	Soft

Conclusions.—Water that is perfectly healthful, so far as freedom from disease germs is concerned, can be had by dug or bored wells less than 50 feet deep at many points in the county, provided the wells are not located near sources of pollution, and are properly cased or lined, preferably with tile. Soft, iron-free, artesian waters can be had anywhere, but pumping will be necessary at places more than 20 to 35 feet above sea level.

At Warsaw, elevation 105 feet, good supplies can be had by sinking a 6-inch well to the Calvert sands about 300 feet below the level of the Courthouse. There is also a possibility of obtaining water in the sands at 225 feet down. From neither of these sands will the water rise to 50 feet of surface.

SOUTHAMPTON COUNTY.

General description.—Southampton County, formed in 1784 from Isle of Wight, lies between Sussex County and the North Carolina line, its north end being 30 miles southeast of Richmond.

The county has a rolling surface. It is traversed by Blackwater and Nottoway rivers, which unite to form the Chowan at the southeast corner of the county, and is bounded on the southwest by Meherrin River. These streams flow through rather open valleys and meander across low terrace plains, and their tributaries are called swamps. A large part of the surface is included in the Sunderland and Wicomico terraces. Later Columbia terraces can be traced along the river valleys, but their total extent is undetermined. The maximum elevation of the highest terrace is about 110 feet near Joyner, Ivor, in the northern part of the county, has an elevation of about 90 feet. The highest ground in the vicinity of Franklin is 84 feet above sea level. In the valleys of Meherrin, Nottoway, and Blackwater rivers in the southern part of the county, a low Columbia terrace, with an elevation of 20 to 25 feet above tide water, covers large areas. The extent of the low terraces, those less than 40 feet above tide, is an important question since it is along them that flowing wells are to be had.

Geology.—The sandy loams of the Columbia formations hide the older deposits over nearly all the county, the Chesapeake (Miocene) sands and marls being exposed here and there on valley slopes. The base of the Chesapeake is about 20 feet above sea level in the west end of the county and 120 feet below near Franklin, evidently dipping eastward about 4½ feet per mile. The Chesapeake thins to feather edges at the west, but is 200 feet thick on high ground in the northeast end of the county. The Pamunkey (Eocene), Potomac (Lower Cretaceous), and Upper Cretaceous beds underlie the Chesapeake group under part of the county, but toward the southwest the Pamunkey beds thin out and disappear and the Chesapeake rests directly on the Potomac. Even at Franklin there is no positive evidence that the Pamunkey is present. At Emporia, in Greenesville County, 2 miles west of the west corner of Southampton County, crystalline bed rock comes above sea level, so that the thickness of the

Potomac and Upper Cretaceous beds in Southampton County varies from almost a feather edge to possibly 900 feet at Franklin.

UNDERGROUND WATERS.

Distribution and quality.—The Columbia sands carry plenty of water, which at many places is hard; in low ground the shallow water is not considered healthful. The depths to the water table vary with differences in topography, but in general water lies not more than 20 feet below surface. In the southern, eastern, northern, and western parts of the county artesian waters under heads of 25 to 50 feet above tide are found, in the sands of the Potomac group or of the Upper Cretaceous; well drillers say the sands at Arringdale, Hugo, Branchville, Boykins, Delaware, Courtland, and Franklin are white and contain much mica, and more or less lignite, called "wood" or "coal." In places the sands are apparently arkosic. As no fossils have been saved from bore holes, the exact age of the sands is in doubt. Similar sands are reported at Margaretsville, on Meherrin River in North Carolina. The artesian waters show considerable differences. In general they are soft and alkaline and well adapted to household use, but at some places they contain iron and have a distinct sulphur odor.

Springs.—While there are in the aggregate many springs along the creeks of Southampton County, most of them issue as seeps rather than strong flows, and in some sections of the county springs are relatively scarce. A few are used for household supply but none are of commercial importance.

Wells.—Southampton County probably contains more drilled wells than any other county of Tidewater Virginia except King William. The total number may exceed 300. Nearly all are 1½ or 2 inches in diameter. Depths range from 75 to 344 feet, and costs from 25 to 50 cents per foot. On the higher ground dug wells are the main source of supply for farms and villages. The usual price for digging is $5 for 30 feet. There are some bored wells and many driven wells in the county.

LOCAL SUPPLIES.

At Branchville are about 17 wells that develop a water-bearing sand in Potomac or Upper Cretaceous beds. The depths range from 130 to 250 feet and the heads are 45 to 50 feet above sea level, the level of the railroad station being taken as 46 feet. The flows are from 1 to 8 gallons per minute. As many as four flows have been found by one well.

The following general section at Branchville is reported by R. G. Ellis & Son, well drillers.

General section at Branchville.

Material	Thickness (Feet)	Depth (Feet)
Surface soil, sand and clay	10	10
Yellowish sand, water	11	21
Soft blue mud	13	24
Blue marl, with shells	17	41
Sand, with lignite	9	50
Red and white clay, with sand layers	60	110
White sand, contains mica and lignite and at some wells much kaolin, water-bearing	45	155

Other water-bearing sands lie below, separated by clayey beds. The well of T. J. Harrell found flows at 90, 110, 160, and 207 feet.

The artesian water is of good quality, although having a faint sulphur odor and being slightly iron-bearing at some wells.

At Boykins, 3 miles east of Branchville, about 25 wells, mostly for household supply, have been driven to Upper Cretaceous or Potomac beds, the succession of surface soil, clay, sand, blue mud, marl, reddish clay, and sand being much the same as at Branchville. The wells range in depth from 85 to 130 feet. The water is soft, but at some wells carries a little iron and is sulphur-bearing. An idea of its mineralization may be had from the field assays in table 8.

Near Arringdale are several small diameter wells that get flows from white micaceous sands below clay and marl. The wells go 70 to 75 feet below the surface of a swamp, elevation about 70 feet. They are used for household supply and for stock.

The Tidewater Railway Co. (Virginian Railway) has at Sebrel the largest and deepest well reported in the county. It is 10 inches in diameter and goes down 344 feet. It probably draws on Potomac sands. The following record was kept by the driller:

Record of well of Tidewater Railway Co., Sebrel.

(Authority, Tidewater Railway Co., owner.)

Material	Thickness (Feet)	Depth (Feet)
Clay	10	10
Clay and sand	20	30
Light blue mud	21	51
Blue mud and sand	10	61
Blue mud	51	112
Sand and gravel	10	122
Blue clay	32	154
Sand and clay	13	167

Record of well of Tidewater Railway Co., Sebrel—(Continued).

Material	Thickness (Feet)	Depth (Feet)
Blue clay	8	175
Fine yellow sand	11	186
Blue clay and sand	5	191
Coarse sand and gravel; water	21	201
Hard blue clay	4	206
Dark mucky clay	18	224
Blue clay	12	236
Soft mucky blue clay	53	289
Blue clay	53	342
White sand and water-worn gravel with pebbles the size of a small egg; water-bearing	....	342

The water level of this well when completed was 21 feet below surface, elevation 55 feet. For a test the well was pumped steadily 18½ hours at the rate of 106 gallons per minute. This lowered the water to 48 feet below surface, but after pumping ceased the water rose gradually to within 15 feet of surface. The well was drilled for locomotive supply. The water contains sodium bicarbonate, as indicated by the analysis in table 7d, and has a tendency to foam. The water at 191 to 202 feet rose to 30 feet of surface.

At Ivor on high ground, 4 miles west of Zuni, the Shaw Lumber Co. sunk a deep well to procure supplies to supplement those obtainable from dug wells. It draws on Upper Cretaceous or Potomac sands. The following log is reported:

Record of well of Shaw Lumber Co., Ivor.

(Authority, Shaw Lumber Co., owners.)

Material	Thickness (Feet)	Depth (Feet)
Earth, marl, quicksand and blue mud	106	106
Blue mud and clay	89	195
Green mud	6	201
Black sand and gravel, with a small supply of water	19	220
White sand and small gravel	17	237
White sand with layers of blue mud	19	256
Water-bearing sand	31	287

The water from the bottom rises to 35 feet of the surface; the yield by air-lift is 55 to 60 gallons per minute. The 6-inch casing is finished with a No. 6 Cook strainer, 20 feet 6 inches long.

At Courtland are many flowing wells, possibly 75. T. J. Moore, of Storeys, reports having put down more than 50. Yields average about 10 gallons through a 2-inch pipe at surface, but vary from 1 to 50 gallons, depths and yield depending partly on the elevation of the well. Where wells are thick, yields and heads have been reduced by interference, those on low ground draining those on higher ground. The original head was about 27 feet above sea level, and on the high ground, elevation about 30 feet above the Nottoway River, wells have to be pumped. The following general record is reported by Mr. Moore:

General section at Courtland.

Material	Thickness (*Feet*)	Depth (*Feet*)
Soil, clay and sand; water at 6 feet	13	13
Blue mud	23	36
Marl and blue mud	60	96
Yellow pipe clay	24	120
White micaceous sand with "wood," water-bearing, water rising about to surface	2	122
Yellow pipe clay	8	130
White micaceous sand with "wood"; water at 130 feet rising 12 feet above surface	15	145

A 2-inch well at the level of the main street, about 20 feet above Nottoway River, flows 25 gallons per minute. The artesian water is of excellent quality for household use, containing very little iron and having no sulphur odor. In a boiler it foams. Results of a field assay appear in table 8.

At Franklin a large number of wells have been put down, perhaps 150. Depths average 130 feet, but vary since surface elevations in the town range from 10 to 35 feet above river level. The water comes from higher sands than those tapped by the Courtland wells, and are presumably of Upper Cretaceous age. The following succession is reported by T. J. Moore:

General section at Franklin.

Material	Thickness (*Feet*)	Depth (*Feet*)
Soil clay and sand	15	15
Blue mud	20	35
Blue marl and shells	40	75
Blue pipe clay	25	100
Hardpan or marl rock; drilled 14 inches in 3 days	1	101
Dark clay, like blue mud above	30	131
Hardpan or marl rock	½	13½
Clay and sand	8½	140
Hardpan or marl rock	½	140½
White micaceous sand, with "chunks of wood," water-bearing	24½	165

The average flow of 2-inch wells at the level of the main street, 20 feet above high tide in Blackwater River, is 4 gallons per minute. On "the ridge," the higher ground in town, elevation over 34 feet, the wells have to be pumped, as the water will not rise over 26 feet above high tide.

Flowing wells have also been drilled on Meherrin River west of Branchville, at Hugo, and south of Boykins, on Nottoway River several miles north and south of Courtland, and on Blackwater River as far north as Zuni, though no wells are reported on the Blackwater between Zuni and 5 miles from Franklin; south of Franklin deep wells are reported for 5 miles.

The following statement summarizes the information collected regarding dug wells at various places in the county:

Details of dug wells in Southampton County.

Location	Depth of well *(Feet)*	Water bed	Quality of water
Aidyl	15–30	....	Soft
Assamoosick	6–60	Loam, sand and marl.	Soft
Conley	15–20	....	Fair to good
Ivor	10–17	Blue clay	Soft
Maury	10–40	....	Soft
Newsoms	10–30	....	Soft
Sunbeam	15–25	....	Soft, hard; deep, irony.
Unity	12–16	Sand and marl	Soft to hard
Worrells	22	Sand	....

Conclusions.—Enough drilling has been done to indicate that flowing wells of good water can be had in this county on the low terraces along Blackwater River below McClelland, along Nottoway River below 10 miles north of Courtland, and along Meherrin River below 10 miles east of Emporia. Flows are not to be expected on the higher divides between the main rivers, but can be had up many tributaries for considerable distances. Where, as at Courtland or Franklin, heads have fallen and flows grown smaller by allowing wells to run without restraint more water can be had by going deeper.

SPOTTSYLVANIA COUNTY.

General description.—Spottsylvania County, formed in 1720 from Essex, King William, and King and Queen counties, lies between Rappahannock and North Anna rivers. Only a small part of the county near the eastern border is included in the Coastal Plain. The topography of this portion of the county is as a whole hilly, but there are extensive level stretches 50 to 70 feet high along Rappahannock River, and also on the high Lafayette plain, which has an elevation of 250 feet south of Fredericksburg.

In the valleys of the main streams west of Fredericksburg the crystalline gneisses and granites are exposed. They are overlain by the arkosic gravels and sands of the Potomac (Lower Cretaceous) and further south by the sandy clays and sands of the Chesapeake (Miocene). Near Massaponax Creek, Pamunkey (Eocene) greensands weathered to reddish and buff tints separate the Potomac from the Chesapeake beds. The Columbia cobble beds, sands, and loams rest in places directly on bed rock, in places on Potomac, in places on Pamunkey, and in places on Chesapeake beds. The Potomac group has a maximum thickness of 300 feet in the extreme northeast corner of the county. The Pamunkey and Chesapeake are thinner. The Chesapeake is everywhere above sea level, and only a small portion of the Pamunkey is below.

UNDERGROUND WATERS.

Distribution and quality.—The coarser beds of the Lafayette and the several Columbia formations are the most important reservoirs of ground water. The supplies generally are soft and slightly mineralized, but in places the water in the 60-foot terrace formation is decidedly iron-bearing. In the Pamunkey and Chesapeake sands the water varies from hard to soft. Little is known of the Potomac sands below tide level.

Springs.—Because of the water-bearing sands in the Lafayette and lower-lying terrace formations being uncovered along scarps, springs are numerous. Most of them are small, a few show bold flows and several in the vicinity of Fredericksburg have been long used by the public. Two of these, known as the Mint and the Gunnery springs, are owned by the city. They have covered masonry basins which exclude trash and surface wash during storms. Each spring flows from the base of a terrace, and the terrace immediately back of each spring is rather densely populated. The water from neither spring can be regarded as safe from pollution, though the danger at the Gunnery spring is less than at the Mint spring. In 1906, the water from both springs was drunk by a considerable number of people, particularly in the summer, because of its coolness and clearness.

Another spring, known as the Silk Mill spring, issues from the base of the same terrace, near the river, in the northwest part of the city. It has been used more or less by people living in the vicinity, but an investigation by the local Board of Health in 1905 indicated that the spring water was dangerous and should not be drunk unless boiled.

Besides these springs, several near the base of the Lafayette scarp on the heights a mile west of the city are utilized for public service by the Aqueduct Water Co. The water is clear and soft.

Wells.—Dug wells are the main source of supply. Depths vary greatly; in hollows on the top of the high Lafayette terrace are wells less than 15 feet deep, while near the edge of the terrace depths range up to 40 feet. Along lower slopes depths are from 20 to 30 feet.

On the broad terrace plain along Rappahannock River southwest of Fredericksburg, wells are dug to depths of 10 to 15 feet. In Fredericksburg is a number of dug wells 20 to 40 feet deep. Several near the river front, used for boiler supply, obtain rather hard water from Potomac beds.

In 1906, there was but one deep well in the city of Fredericksburg, that owned by E. D. Cole. This well is 120 feet deep and yields water of low mineral content. Mr. Cole uses the water for household purposes and furnishes it for drinking to neighbors who desire water more refreshing and less liable to pollution than that from the turbid Rappahannock. An analysis furnished by the owner, but recalculated to standard form, appears in table 11.

Fredericksburg is supplied with raw Rappahannock River water distributed by the city waterworks. In addition a private corporation, the Fredericksburg Aqueduct Co., distributes the water from the springs on the heights back of the town to a limited number of subscribers. This company is one of the oldest water companies in the United States giving an uninterrupted service, the springs having been developed as far back as 1823. Water was distributed for many years through bored logs and lead pipes. With ordinary care in maintaining the pipes leading from the springs to the supply basin, and in protecting the latter, these springs can furnish a drinking water of satisfactory quality, so long as the terrace above them is sparsely inhabited; but the flow is so small that the use must be limited.

Conclusions.—The gravels and sands, and even the non-clayey beds on the terraces along the river and on the divides, yield water in sufficient quantity for all the requirements of isolated dwellings and farm supply. Deep wells at and southeast of Fredericksburg will probably get good water from the Potomac beds. Flows can not be expected on the 60-foot terrace, though the water may rise above tide level.

STAFFORD COUNTY.

General description.—Stafford County, formed in 1765 from Westmoreland County, lies on the west bank of Potomac River north of Rappahannock River which forms its southern boundary. The Coastal Plain portion is a narrow strip along Potomac River.

Valleys deeply cut by Potomac, Aquia, and other creeks emptying into Potomac River give a rugged topography with comparatively few stretches of level ground. The maximum elevation, a little over 250 feet, is on a patch of the Lafayette plain, northeast of Fredericksburg. There are some level stretches on a low Columbia terrace along Potomac River, with elevations of 35 to 45 feet. Near the mouth of Aquia and Potomac creeks are cliffs 50 to 100 feet high.

Geology.—The soil over most of the Coastal Plain portion of Stafford County is derived from the Potomac (Lower Cretaceous) clays, shales, sands, and gravels. In places the Pamunkey (Eocene) greensands, weathered yellow, orange, and red, form the surface material, the largest area of Pamunkey being in the extreme southeast corner of the county. In this same part of the county a thin sheet of the Chesapeake (Miocene) rests on the Pamunkey, the only occurrence of Chesapeake beds in Stafford. The Lafayette and Columbia cobble beds, sands, and loams, as a rule brightly colored, rest on Potomac, Pamunkey, and on Chesapeake beds. The maximum exposed thickness of the Potomac is about 250 feet, and its thickness in the southeast corner of the county may be 350 feet. Nearly all the Pamunkey beds lie above sea level and no Chesapeake beds extend below it.

UNDERGROUND WATERS.

Springs are numerous but few are of especial note. They and dug wells are the sources of domestic supply. Depths to water and quality of water vary from place to place; in general the ground water is good. Excellent water can be obtained, no doubt, from the Potomac beds, but no deep wells have been sunk to determine the depth to water-bearing sands or the quality of the water. Flows are not to be expected.

Dug well conditions at a few points in the Coastal Plain portion of the county are summarized as follows:

Details of dug wells in Stafford County.

Location	Depth of well *(Feet)*	Water bed	Quality of water
Brooke	15–40	Sand and marl	Soft to slightly hard.
Falmouth	15–30	Sand	Soft to hard
Leeland	20–50	Sand	Soft
Millin	20–100	Soft rock and sand	Soft
Stafford	25–50	Sand and rock	Soft and hard

SURRY COUNTY.

General description.—Surry County, one of the original eight shires of Virginia, lies south of James River, in the western part of the Coastal Plain. Most of the surface of the county is included in the Sunderland plain and is rolling, with a gentle slope to the southeast. Near the northern edge of the county Chipoak, Grays, and other creeks flowing to James River have cut sharp valleys. As in Prince George County to the west, the southward flowing streams, such as Cypress Swamp, tributaries of Blackwater River, have open valleys. The divide is but a few miles back from James River. The Sunderland plain is, as a rule, below 100 feet high, its maximum elevation near Ruffins and Spring Grove being 130 feet. Low terraces occupy a very small part of the county. They are most noticeable south of Hog Island. For considerable distances, the southern bank of the James is steep and high, and the river cuts directly into the Sunderland terrace, as at Claremont.

Geology.—The Columbia (Pleistocene) formations cover most of the county. The Chesapeake (Miocene) group outcrops in the bluff at Claremont and is exposed in creek gullies. South of the divide the Chesapeake shell beds have been dug for marl in pits along tributaries of Blackwater River. The maximum thickness of the Chesapeake group in the western corner of the county is probably 150 feet, its base lying 50 feet below tide. In the eastern part of the county near Hog Island the base of the formation may be 350 feet deep. The Pamunkey does not outcrop within the county limits. Its base is about 350 feet below sea level at Claremont and 500 feet below at Homewood. The Potomac is over 500 feet thick and crystalline bed rock is fully 800 to 1,500 feet below sea level.

UNDERGROUND WATERS.

Distribution and quality.—Surry County is well watered by its numerous creeks. The ground water in the Columbia beds is generally soft, but in places is of indifferent quality. Ground water in the Chesapeake marls is at many places hard. Depths to water vary greatly. In the wide pocosons on the east side of the county the water rises to the surface after wet seasons, and is never more than 10 feet below it, while on high ground overlooking James River the water table may be 40 feet below the surface.

Plenty of artesian water underlies Surry County in the Chesapeake, Pamunkey, and Potomac sands. Both the Chesapeake and Pamunkey waters are soft and are more or less alkaline. No attempt to reach Potomac sands is reported, but it is altogether probable that they will yield plenty of water.

Springs.—Surry County is abundantly favored with springs, nearly all the creeks and branches being spring fed. Many of the small springs and seeps fail in time of drought, but the deeper springs in the northern part of the county and the "boiling" springs in the southern part are perennial. Most of the springs are little used except by stock, but a few furnish household supplies. Near Claremont are several with bold flows. Some from beds of marl yield water that is slightly hard and is said to have a marly taste. There are people who consider such water unhealthful, but where the ground above the spring is thinly settled, the marl bed overlain by a thick layer of loam, and surface waters can not reach the sources of the spring through poorly protected dug wells, there is no reason for judging the healthfulness of the water by the taste. A complete analysis of water from a marl spring south of Claremont, given in table 6, shows that the water contains notable amounts of bicarbonate of soda. A marl spring north of the village supplies several families. Another spring just east of the city has been improved by the owner, E. E. Harry, who markets the water as Trepho Lithia water. This spring flows from iron crusts and sands in the Sunderland formation. Various improvements have been made at this spring, and precautions have been taken to maintain the sanitary excellence of its surroundings. The following analysis is recomputed from one furnished by the owner:

Analysis of Trepho Lithia water.

(J. B. Weems, analyst.)

	Parts per 1,000,000
Total solids	573.
Silica (SiO_2)	34.3
Aluminum (Al)	1.95
Iron (Fe)	2.88
Calcium (Ca)	115.
Magnesium (Mg)	3.22
Sodium (Na)	11.2
Potassium (K)	2.12
Lithium (Li)	0.03
Bicarbonate radicle (HCO_3)	395.
Sulphate radicle (SO_4)	3.82
Chlorine (Cl)	3.46
Free carbon dioxide (CO_2), 3.5 c. c. per liter.	

A group of marl springs just south of Dendron was, at one time, used for boiler supply at the mills of the Surry Lumber Co., but the water was so limy and formed so much scale that the springs were abandoned. Other springs in the county deserving note are one, 2 miles southeast of Anchor, and one 2 miles northeast of Surry, on the road to Scotland. A few springs supply houses by rams; there is one at Bacon's Castle.

Wells.—Open dug wells, often provided with the old-time sweep and bucket, constitute the most important source of water for household use. Prices for digging these average about $5. Most of them have no lining but a wood "curb" at the bottom. The cost of such wells complete has often been less than $15. A few of the dug wells are bricked or cased with tile; the proportion of the latter is increasing. In dry seasons many of the shallow wells fail. There are some bored wells and some driven wells, and along James River a few drilled wells. At a number of points near the river the ground waters are so limy or irony that cisterns are used.

LOCAL SUPPLIES.

At Dendron most people obtain water from dug wells, 14 to 20 feet deep. There is also a considerable number of driven wells 18 to 20 feet deep, the water from which is considered better than that from dug wells. Both dug and driven wells get water from sands in the Sunderland formation. This water is soft and adapted to household use. A well drilled some years ago for the Surry Lumber Co. to a depth of 386 feet was abandoned as unsuccessful because it did not give a flow.

At and near Surry Courthouse dug wells average about 20 feet deep. Ordinarily they have from 5 to 8 feet of water in them, but in wet seasons some of the shallow ones are filled to the surface. Most of the wells are lined with wood, though a few are cased with tile. The following section is reported:

Section at Sunny Courthouse.

Material	Thickness *(Feet)*	Depth *(Feet)*
Soil	1	1
Yellow clay	12	12
Slate-colored, sandy clay	8	20
Vari-colored clay, pebbles at 35 feet	20	40
Marl	3	43
White gravel; water	4	47

At Claremont, situated on a headland of the Sunderland plain, dug wells are from 20 to 40 feet deep. These yield water of varying quality; some is from shell beds and so hard as to be unsatisfactory for domestic use. Some of the wells are liable to contamination because of insufficient protection at the surface, others because of seepage from old polluted wells nearby. In 1906, cisterns were used by fully one-half of the population; about one-fifth used wells; the balance used spring water. At some of these springs are rams supplying tanks at dwellings. The water is generally soft.

On Homewood plantation on Hog Island in James River are 6 flowing wells, all sunk 20 years ago. Their depths are variously stated, but all draw on Chesapeake beds. A 6-inch well is said to have been sunk 317 feet, and to have struck a strong sulphur water at 270 feet, and a good flow, 40 gallons per minute, in a shell bed at the bottom.

The following record of one of the wells has been published by Darton[a]:

Record of well at Homewood.

Material	Thickness *(Feet)*	Depth *(Feet)*
Clay and loam	15	15
Gravel with surface water	10	25
Clay, blue below	60	85
Shell marl with hard crust of shell at base, flow of ferruginous water at 112 feet	37	112
Marl	108	220
Rock	1½	221½
Blue clay with flow of water at 222 feet, water better than at 112 feet, and greater flow	67½	289
Hard rock	2½	291½
Black, water-bearing sand; fine water, flow at surface 30 gallons per minute through 1½-inch pipe, head 40 feet	....	291½

It is not possible to determine to which of the wells at Homewood this record refers.

A complete analysis from a well in the southeast corner of the plantation appears in table 8. The water has a faint sulphur odor when fresh. The well is said to be 219 feet deep; it may be deeper.

Another well south of Homewood and 4 miles east of Bacon's Castle was sunk for a brickyard, since abandoned. It is said to be 400 feet deep, but the water has all the characteristics of the Chesapeake flows. An attempt to get a flow at Bacon's Castle was unsuccessful, the elevation of the post-office being 84 feet above tide.

Shallow well conditions at a number of villages in Surry County are summarized below:

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[a] Darton, N. H., Op. cit., p. 174.

Details of shallow wells in Surry County.

Location	Depth of well *(Feet)*	Water bed	Quality of water
Alliance	15–40	Marl	Shallow, soft; deep, hard.
Anchor	12–35	Sand	Shallow, soft; deep, soft to hard.
Bacon's Castle	15–40	Sand and marl	Soft to hard
Cabin Point	16–30	Sand	Soft to hard
Claremont	40–60	Sand and marl	Hard
Dendron	12–26	Shallow, clay; deep, clay and marl.	Shallow, soft; deep, hard.
Elberon	8–25	....	Fair to good
Hargrave	20	Sand	Soft
Ingenall	50	Marl	Hard, cistern
Ruffins	8–40	Sand and marl	Deep, hard
Savedge	10–24	Clay	Fair to good
Scotland	60–80	Iron crusts and marl.	Limy and irony
Spottsville	10–80	Shallow, sand; deep, marl.	Shallow, soft; deep, hard.
Surry	15–40	Sand, marl	Soft
Wiedman	35–45	Sand and marl	Hard

Conclusions.—Plenty of good water can be had in Surry County by dug, driven, or drilled wells. Artesian waters that will rise 20 to 35 feet above sea level can be had anywhere. Their quality will be found excellent for most purposes, but toward the east side of the county they may not be altogether satisfactory for certain industrial uses.

At Dendron, where the question of obtaining better water than that afforded by shallow wells will demand attention with the growth of the town, plenty of water can be had from the basal Chesapeake sands at 300 feet, or the Pamunkey sands at 550 feet, by 8-inch wells and pumps or air-lifts. Flows are impossible. In the swamp along Blackwater River south of the town, the Pamunkey waters may rise to surface. Flows are impossible at Surry, the elevation of the ground at the Courthouse being about 100 feet. By drilled wells and pumps soft alkaline water can be had at about 400 feet.

In case artesian water is sought for town supply at Claremont, a well or wells near the foot of the bluff will probably be more satisfactory than wells in the center of the town. In the latter situation flows can not be had, the altitude being 90 feet, but flows can probably be had near the river and it will be more economical to locate a pumping station there than to use deep well pumps.

SUSSEX COUNTY.

General description.—Sussex County, formed in 1754 from Surry County, is separated from the latter by Blackwater River. It extends from Blackwater River to Nottoway and Meherrin rivers, and is about 40 miles long from its northeastern to its southwestern corner. The southwestern corner of the county lies west of the Piedmont-Coastal Plain boundary. The two most important towns are Waverly and Wakefield.

The topography varies from slightly rugged in the southwest to undulating in the northeast. The larger portion of the surface is included in the Sunderland terrace. The maximum elevation reported is near Jarratt, 155 feet; the minimum is on the banks of Meherrin River near Emporia, 25 feet. The general slope of the surface is southeast. Coppahaunk Swamp and Warwick Swamp flow northeast to Blackwater River; Joseph's Swamp, Stony Creek, Roaring Creek, Poplar Spring, and Assamoosick Swamp flow south or southeast to the Nottoway.

Geology.—While the Chesapeake (Miocene) clayey sands and marl beds underlie practically all the county as far east as the Atlantic Coast Line Railway they are seldom exposed, owing to the coating of Columbia (Pleistocene) loams and sands. On the west the St. Mary's formation of the Chesapeake overlaps the Potomac beds and rests directly on the crystalline rocks. Its shell or marl beds have been opened by many small pits and dug for fertilizer. Pamunkey (Eocene) beds probably underlie the Chesapeake east of Sussex but are not known to outcrop anywhere in the county. At Bolling's Bridge on Nottoway River is an outcrop of a bed of cobbles and pebbles that has been regarded as a basal bed of the Potomac group, Lower Cretaceous; it may belong to the Chesapeake. From feather edges the Chesapeake and older formations thicken eastward and at Wakefield the base of the Chesapeake is probably 300 feet below the surface, the base of the Pamunkey 50 feet deeper, and the crystalline bed rock not less than 700 feet below. The surficial sands, gravels, and loams belong to the Sunderland, Wicomico, and Talbot formations of the Columbia group.

UNDERGROUND WATERS.

Distribution and quality.—The abundant ground water in the Columbia sands and Chesapeake sands and marls varies in quality from soft to hard, and in places is irony. Artesian waters underlie the eastern half of the county. Little is known of them, but it is safe to say that they are of excellent quality. There are no flowing wells in the county but it is likely that some artesian waters will rise to the level of the swamps along Nottoway River south of Lumberton.

Springs.—There are numerous springs and seeps along the rivers and their tributaries. Nearly all issue from the white sands which mantle the valley slopes and their geologic source can not be determined by inspection. Most are of small flow and many fail in droughts. The springs are little used except for watering stock. The only one in the county of commercial note is the Coppahaunk on Coppahaunk Swamp, about 1½ miles south of Waverly. It has had considerable repute and is now owned by persons who bottle and ship the water. The flow is free, about 25 gallons per minute. The water rises through sand and probably comes from a Chesapeake shell bed; it is iron-bearing and is said to have slight sulphur taste when fresh from the spring. The following analysis is recomputed from one furnished by the company:

Analysis of water of Coppahaunk Spring, Waverly.

(Froehling & Robertson, analysts.)

	Parts per 1,000,000
Total solids	293.
Silica (SiO_2)	23.
Iron (Fe)	0.7
Aluminum (Al)	9.9
Manganese (Mn)	trace
Calcium (Ca)	93.
Magnesium (Mg)	1.5
Strontium (Sr)	0.1
Barium (Ba)	0.15
Zinc (Zn)	faint trace
Sodium (Na)	5.4
Potassium (K)	2.9
Lithium (Li)	0.19
Arsenate radicle (AsO_4)	0.034
Phosphate radicle (PO_4)	0.12
Carbonate radicle (CO_3)	143.
Sulphate radicle (SO_4)	1.6
Iodine (I)	trace
Bromine (Br)	trace
Chlorine (Cl)	11.

Wells.—Dug wells, generally cased with wood, are the main source of supply at most farms, and in many villages. The cost of digging these is low. There are some bored wells and at Waverly and Wakefield many driven wells. No deep drilled wells are reported.

LOCAL SUPPLIES.

At Wakefield there are a few dug wells and over 75 driven wells, the latter from 19 to 22 feet deep. They get soft water in sands underlying loam. A peanut mill gets water from an 80 horsepower tubular boiler from two dug wells about 15 feet deep. The supply is fairly good for boiler use though it has a tendency to form scale. (See table 7.)

At Waverly, where are large lumber mills, nearly all the water for both boiler and domestic supply is obtained from driven wells, which range in depth from 15 to 35 feet. Dug wells which strike the first water bed at 15 feet sometimes fill to the top and are liable to pollution. The water from the second sand, at 30 to 35 feet, is preferred by those persons who have had wells driven to it, and is certainly less liable to pollution than that from 15 feet. In fact, in 1906, this 35-foot water was as good as need be, as no dug wells had been sunk deep enough to permit direct pollution of the water bed. The yields to pumps are remarkable. One 35-foot well, 2 inches in diameter, is stated to give 30 gallons per minute, while at the plant of the J. D. Gray Lumber Co., 2 wells furnish water enough for 250 horsepower. As a boiler water, though considered hard, it seems satisfactory, forming very little scale. Its quality is indicated by a field assay in table 7.

The expense for a 35-foot well at Waverly is slight. A 2-inch pipe can be driven for about $5, and the well equipped with a pitcher pump costs about $10.

Information collected regarding dug wells at various places in the county is summarized as follows:

Details of dug wells in Sussex County.

Location	Depth of well *(Feet)*	Water bed	Quality of water
Airland	20–60	Clay	Irony
Booker	10–30	Shallow, clay; deep, "black mud."	Soft
Comans Well	15–30	Clay	Fair, good
Hilda	10–50	Sand, marl	Soft and hard
Jarratt	12–30	Gravel	Soft
Lumberton	6–30	Shallow, sand; deep, clay or marl.	Soft and hard
Masons	7–35	....	Soft
Peanut	15–20	Loam	Soft
Westhope	8–40	Sand and clay	Soft

At Jarratt some wells dug for boiler supply are 16 feet square and 20 feet deep.

WARWICK COUNTY.

General description.—Warwick County, one of the smallest counties in the State, was one of the eight original shires of the colony of Virginia. It lies along the north bank of James River near the end of "the peninsula."

The topography is somewhat diversified though the relief is not great. The northern part of the county lies within the Sunderland terrace which has an elevation of 86 feet at Halstead's Point, in the extreme northern corner. The greater part of the county is included in lower terraces. The lowest plain includes Mulberry Island. The city of Newport News stands on two terraces.

Geology.—Columbia (Pleistocene) sands and loams mantle the surface. On the lower terraces are local lenses of clay that have been worked for brick on Mulberry Island and at Morrison. At Newport News dark bluish mud containing cypress stumps and bluish sand containing marine shells outcrop in the river bluff beneath gray pebbly sands.

Clayey sands and beds of shell marl mostly belonging to the Yorktown formation of the Chesapeake group (Miocene) are exposed in the creek valleys. The total thickness of the Chesapeake at Halsteads Point is about 450 feet, and at Newport News about 550 feet, its base lying 400 to 550 feet below sea level. The Pamunkey (Eocene), Upper Cretaceous, and Potomac (Lower Cretaceous) lie below the Chesapeake. The base of the Pamunkey is about 600 feet below tide at Halsteads Point, and 700 feet below at Newport News. Evidence as to the thickness of the Upper Cretaceous is contradictory. The base of the Potomac lies over 2,000 feet below tide at Newport News.

UNDERGROUND WATERS.

Distribution and quality.—The ground waters in the Columbia and Chesapeake beds show the usual variations in quality; here soft and clear, there hard and irony. Depths to the water table differ considerably, and where it rises to the surface after prolonged rains, as on flat stretches, the quality of the ground water is not considered so good as where the water table lies deeper.

An abundance of artesian water underlies the county but that so far developed is rather highly mineralized, the mineralization increasing toward the southeast. This increased mineralization is due in part to the water-bearing sands growing finer, and as a result yields to wells and heads of flows are least in the wells farthest down the river.

Springs.—There are no springs of especial importance in Warwick County, but a few are still used for household supply. The smaller springs seep from Columbia sands; the larger flow from shell beds in the Yorktown formation. The waters of the latter are apt to be hard. Some of the larger springs are so situated that they can be advantageously developed by rams.

Wells.—Dug wells are chiefly used. There are a few drilled wells along James River. Near Newport News there are numerous driven wells and a few at other places in the county.

LOCAL SUPPLIES.

The Newport News Water & Power Co. supplies the city of Newport News with water from a watershed it owns. Practically every one in Newport News uses this water, though on the outskirts of the city are shallow, driven and dug wells which obtain supplies, in some instances of suspicious purity, from Columbia sands. Attempts to get artesian water at Newport News have been mentioned. (See page 97.) The artesian wells in the county are all near James River. There are two on Mulberry Island, one at Mulberry Island post-office, the other at Curtis Point. Both of these wells probably get water from sands in the Chesapeake group at 360 to 380 feet below mean high tide. The owner of the well at the post-office has shipped more or less of the water to Newport News and Norfolk. It is soft, clear and refreshing, and has some local repute for medicinal properties. The accompanying analysis furnished by the owner, but recomputed to standard form, shows the large proportion of bicarbonate of soda characteristic of artesian wells in other parts of the Virginia Coastal Plain.

Analysis of water from well of P. H. Wright, Mulberry Island.

(W. H. Taylor, analyst.)

	Parts per 1,000,000
Silica (SiO_2)	13.0
Iron (Fe)	trace
Calcium (Ca)	4.2
Magnesium (Mg)	1.2
Sodium (Na)	354.0
Potassium (K)	15.0
Lithium (Li)	trace
Bicarbonate radicle (HCO_3)	454.0
Sulphate radicle (SO_4)	44.0
Chlorine (Cl)	273.0

The well at Curtis Point is of interest from its location and the quality of the water. In the latter respect it resembles the well at Mulberry Island post-office, but the water is more mineralized. A complete analysis appears in table 8.

At attempt to get a flow at Menchville on the mainland opposite Curtis Point proved unsuccessful, possibly because of the well being started on too high ground, as the head of the flow at Curtis Point is only about 20 feet above sea level. A well at Lee Hall 406 feet deep reaches a sand having about the same stratigraphic position as that yielding flows on Mulberry Island. The elevation of the well is 42 feet and the water rises within 12 feet of the surface.

Conditions reported from some of the places in Warwick County, where dug or driven wells are the sources of domestic supply, are summarized herewith:

Details of shallow wells in Warwick County.

Location	Depth of well *(Feet)*	Water bed	Quality of water
Denbigh	25–30	Clay and sand	Soft, hard
Halstead Point	30–50	Sand and marl	Hard and irony in deep wells
Lee Hall	18–25	Sand	Soft
Menchville	10–31	Sand	Soft
Mulberry Island	10–15	Sand	Soft, irony

Conclusions.—The wells already drilled indicate that from the Chesapeake sands under Warwick County, moderate heads, 20 to 30 feet, and fair flows at the northwest end of the county with diminishing yields and increasing mineralization southeastward, may be expected. Slightly higher heads and freer flows can probably be had from deeper sands in the Pamunkey, Upper Cretaceous, or Potomac, but heads over 35 feet above tide are not to be expected, nor is there any reason to expect much improvement in quality with depth. Water much better adapted to ordinary household use than the supplies obtained from some shallow wells at many places can be had west of Curtis Point. Farther east the outlook becomes increasingly dubious. Prospects in the immediate vicinity of Newport News have already been discussed. (See pages 97 to 116.)

WESTMORELAND COUNTY.

General description.—Westmoreland County lies south of Potomac River on the "northern neck." The topography is characterized by high terraces with undulating surfaces sharply cut by creek gorges and comparatively level lower terraces. Some of the creeks flowing to Rappahannock River head within a mile or two of the Potomac. Some of those flowing toward the Potomac empty into tidal inlets or rivers, such as Nomini River and Yeocomico River.

Elevations on the Sunderland terrace range from 160 feet in the vicinity of Bainesville to 110 feet back of Kinsale. Near Bainesville is a small area above the general level of the Sunderland, and there is another near Stratford. These areas may be remnants of the Lafayette terrace. Lower Columbia terraces are traceable along Potomac River. A striking feature of the topography of Westmoreland County are the famous Nomini Cliffs which extend for nearly 10 miles along the Potomac between Popes Creek and Currioman Bay. These cliffs in places are 200 feet high. Along Rappahannock River below Wilmont Landing are conspicuous cliffs, in places over 100 feet high.

Geology.—The loams, cobble beds, sands, and gravels of the Columbia formations outcrop in many road cuts and in the river cliffs. The lower formations of the Chesapeake group (Miocene) are exposed in many places. Over 200 feet of the Calvert are visible in the Nomini Cliffs and the diatomaceous clays of the formation are to be seen in the cliffs on Rappahannock River. The base of the Calvert is near tide level on the western edge of the county, while at the mouth of Yeocomico River at Lynch's Point it is 350 feet below. The greensands, clays, and shell beds of the Aquia and Nanjemoy formations of the Pamunkey (Eocene) have a total thickness of about 250 feet, and the base of the Pamunkey is 300 to 550 feet below river level. Little is definitely known of the thickness and extent of the Upper Cretaceous beds. The Potomac group may be 500 to 1,000 feet thick and the crystalline bed rock probably lies from 1,000 to 1,500 feet below tide.

UNDERGROUND WATERS.

Distribution and quality.—The Columbia formation and the top beds of the Chesapeake group carry ground water within the county limits. Near the edges of the highest terrace the water table is 30 to 60 feet below the surface and fluctuates slightly. On flat stretches of the same plain it may fluctuate 15 to 20 feet and rise to the surface after a wet season. The quality of the water varies from soft to irony or hard. Shallow water in the Chesapeake beds is at many places hard.

Sands in the Chesapeake, Pamunkey, and Potomac groups are known to contain artesian water. As the beds dip east the depths to the sands increase in going down the river. At the west end of the county the Chesapeake beds are little below tide level and do not give flows; east of Mount Holly most wells draw on them. The sands most widely developed are at the base of the Calvert formation. Higher sands supply wells at the east end of the county. The Nanjemoy sands have been reached by relatively few wells east of Colonial Beach. The heads of the flows vary but the waters most developed had heads of 15 to 30 feet above tide. All the waters sampled from wells reaching Chesapeake or Pamunkey sands were soft and alkaline.

Springs.—Small seeps and springs that feed the creeks flowing to Potomac River are found throughout the county. So numerous are they that as one man expressed it, a spring can be had on any hillside by a little work with a hoe. A few springs, such as those of R. O. Costenbader near Remus, and Wm. Taylor, opposite Kinsale, furnish drinking water or water for household supply; many are so situated that they can be developed to advantage by rams. From no spring is water marketed and none is a resort.

Wells.—On high ground dug wells curbed with wood are the chief source of domestic supply. Some of these wells are poorly located and very liable to pollution. On the high terraces wells are from 20 to 60 feet deep, on the lower terraces they are seldom over 40 feet and the average depth is under 20 feet. There are some bored and some driven wells, and along the river and the tidal courses of the creeks are many drilled wells of small diameter. The cost of these to the owner has averaged between 25 and 40 cents a foot.

LOCAL SUPPLIES.

No town in the Virginia Coastal Plain has benefited more from the development of artesian water than Colonial Beach. The first deep well was drilled in 1887. Before that all persons, and for some years afterward many persons, drank the water obtained by shallow wells 6 to 15 feet deep, and as a rule poorly protected. Typhoid fever obtained a foothold and was in some years epidemic. Since the substitution of artesian for dug wells typhoid has practically disappeared.

Nearly all the artesian wells reach a greensand in the Aquia formation of the Pamunkey, about 200 feet below river level. According to the driller, who sunk many of the wells in town, none of those reaching this sand is over 220 feet deep. The sand is immediately overlain by some 10 feet or so of red or chocolate-colored clay. The sections reported vary, but the following may be taken as an average:

Generalized section at Colonial Beach.

Material	Thickness *(Feet)*	Depth *(Feet)*
Soil and sandy loam	8	8
Yellow to buff clay	4	12
Gravel and sand	7	19
Blue marl, black sand, dark clay, shells	150	169
White clay	2	171
Red and chocolate-colored clay not over 10 feet thick on beach	10	181
Rather fine green or black sand, water bed	20	201

Some wells pass through "rock" 8 to 10 inches thick in the blue marl at 150 feet. Most of the wells are 1½ inches in diameter and were sunk by hand rigs. Prices for drilling have been $50 to $75, according to care in placing casing, etc.

The water from the 200-foot wells as it comes from the same horizon varies little in quality. It has a slight sulphur odor and is decidedly alkaline (see field assays, table 9). It is used for all purposes. As a boiler water it has a tendency to foam and pit tubes.

At the ice plant where a well to the 200- to 225-foot sands gave an insufficient supply, a well to a sand in the Potomac group found plenty of good water. The driller reported the following log:

Record of well at Ice Plant, Colonial Beach.

(Authority, Roland Rude, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Made land	6	6
Yellow clay	13	19
White clay	2	21
Green marl	39	60
Black earth with sand	140	200
Rocks in coarse brown sand, a little water	100	300
Black earth with large grains of heavy sand	50	350
White clay, with some very soft streaks	50	400
Red clay	15	415
White sand with plenty of water	7	422

The well is 1½ inches in diameter, the flow is 6 gallons per minute at an elevation of 5 feet.

Outside the thickly settled portion of the Beach there are still wells of good flow to the 200-foot sand. One of the best is that of the McGinnis estate at the south end of town, which when dug flowed about 3 gallons per minute at an elevation of 9 feet above high tide.

North of the Beach at Wilkerson's Wharf are two wells, 233 and 235 feet, respectively, flowing 3½ and 1⅗ gallons per minute at elevations of 4 and 7 feet above tide water. The wells are said to have struck the Beach flow at 214 feet but found it a mere drip. After going through 10 feet of white sand and "rock," the latter in layers 1 to 10 inches thick, and 20 feet of "red clay," the present flow was struck which rose 40 feet above sea level and gave 5 gallons per minute.

At L. C. Handy's, west of Wilkerson's, is a well that has a measured head of 22 feet, and flows into a tank about 20 feet above mean high tide. An attempt made to get a flow at an elevation of 30 feet above tide was unsuccessful though the well was sunk 471 feet, according to the driller.

In the vicinity of Erica the sands that yield waters to the wells near the head of Nomini River are apparently too fine to give flows, and several wells have gone to sands in the Pamunkey at reported depths of from 300 to 350 feet. One at the post-office, elevation about 20 feet, is said to be 336 feet deep and to have flowed in 1902 when drilled. In 1906 the water stood about 3 feet below surface.

A mile east of Maple Grove and some 3 miles west of Colonial Beach, a well was drilled in 1905, for Floyd Omohundro, on the Wicomico terrace at an elevation of 60 feet. This well found water in white sand, which rose to about 40 feet of surface. The well is cased for only about 40 feet, and, according to Mr. Omohundro, since it was drilled there has been a change in the quality and yield of the water in his dug well, 45 feet deep, about 20 feet distant, indicating that the artesian water finds its way into the dug well.

At or near Kinsale, on Yeocomico River and its inlets, a considerable number of flowing wells have been put down. Those at Kinsale are said to range in depth from 238 to 275 feet, most of them striking a water-bearing sand in the Calvert formation at 245 feet. The heads average about 17 feet above mean high tide, and the flows at an elevation of 6 feet are about 4 gallons per minute through a 1½-inch pipe. The water, which has a slight sulphur odor, is used at canning factories and also for drinking. In a boiler it works fairly well, not pitting the tubes, but having a tendency to foam. At the canning factories it is the custom to blow off some of the water in a boiler, one or two gages, several times a week. The general character of the water is indicated by the field assays in table 8.

North of Kinsale on Sandy Point Farm, the 5,000-acre estate of J. R. Dos Passos, of New York, there are no less than 15 flowing wells. Many of them are at tenants' houses and were intended to furnish pure water for domestic use, the supplies from shallow wells having, it was thought, caused malarial disorders. A marked improvement in the health of those using artesian water is claimed. The following log was furnished by the driller:

General record of wells near Sandy Point.

(Authority, F. H. Jones, driller.)

Material	Thickness *(Feet)*	Depth *(Feet)*
Loam	17	17
White sand	8	25
Blue clay (called fullers earth)	150	175
Marl and layers of shells	50	225
Thin layers of rock about 2 feet apart, with sand between	5	230
Black sand, water-bearing		230

This water has the general characteristics of the flows at Kinsale as shown by the field assay in table 8.

At Sandy Point farm on the river shore at Lynch Point, is a flowing well but 90 feet deep which may tap a sand in the St. Mary's formation of the Chesapeake. The head of the flow is about 3 feet above high tide. The water decidedly differs from the deeper flows; it contains more iron and lime, as shown by field assay (table 7), and is little used. In a way the well resembles in low head and quality of flow some of the wells in Accomac County.

Near Nomini River there are flowing wells at Mount Holly, Hinnom, Beal's Wharf, McGuire's Wharf, and Erica. Most of them draw on the Calvert sands of the Chesapeake group. The well at Mount Holly is 150 feet deep and flows, at an elevation of 9 feet above tide, about 5 (?) gallons per minute through a 1½-inch pipe. A field assay of the water is given in table 8. Some of the wells on Nomini River tap deeper sands, if reported depths are trustworthy, but the waters are much alike. Most of the wells have cost $40 each.

At Oak Grove, on the Wicomico terrace, several attempts to get artesian flows have failed, owing to the elevation of the surface, 60 feet. Some wells at Oak Grove, at 25 to 30 feet deep, are poorly situated and continually liable to pollution.

Two miles southeast of Oak Grove an attempt to get a flow at the residence of Andrew Flanner failed because of the elevation, though the well went down 664 feet. Mr. Flanner has a dug well 63 feet deep that gets water in Chesapeake sands.

Data collected regarding dug wells at a number of villages in Westmoreland County is summarized as follows:

Details of dug wells in Westmoreland County.

Location	Depth of wells *(Feet)*	Water bed	Quality of water
Bainesville	35–60	Sand and clay	Soft to hard
Erica	12–18	Sand and marl	....
Hague	35–40	Sand and gravel	Soft
Homers	20–45	Sand	Soft
Index	30–45	Sand and gravel	Soft
Kinsale	15–25	Sand and marl	Soft to hard
Leedstown	14–20	Sand	Soft
Machadoc	12–30	Sand	....
Maplegrove	30–60	Sand	Soft
Meter	15	Sand	Hard
Montross	30–50	Sand	Soft, hard
Oldhams	18–60	Clay	Soft
Potomac Mills	15–30	Sand and marl	Soft to hard
Rollins Fork	30–50	Sand	Soft
Remus	30–80	Sand	Good
Templeman Cross Roads	25–35	Sand	Soft
Tuckerhill	16–60	Sand	Good
White Point	18–20	Clay and sand	Soft
Zacata	15–40	Clay	Deep, hard; shallow, soft.

Conclusions.—The volume of flows obtainable by carefully cased wells from the artesian sands under Westmoreland County, the quality of the water, its superiority to the supplies obtained by many dug wells, and its freedom from disease germs, are reasons for more extensive development of these sands. Flows are not to be expected at points more than 35 feet above sea level, but higher heads than those found in the artesian sands nearest surface can be obtained by deeper drilling.

At Oak Grove, soft water free from disease germs can be had by pumps from wells to the Calvert sands at 250 feet, or the Potomac at 450 feet. The water from the latter will rise to about 25 feet of surface.

At Montross the water from the Pamunkey sands, to be reached at 400 feet, will rise to about 70 feet of the level of the Courthouse. In Kinsale, flows at the elevation of the higher ground in the village are impossible; wells to the Pamunkey sands at 500 feet may rise fully 30 feet above the river.

YORK COUNTY.

General description.—York County, one of the original shires of Virginia, lies along the south side of York River on "the peninsula," of which it covers the larger portion. The surface of the county is diversified by tributaries of York River, the more important creeks being Ware, Scimmins, King and Queen, which cut back into the several Columbia terraces. The greatest elevation of the Sunderland terrace, at the northwestern corner of the county, is about 110 feet.

Geology.—The Columbia formations form the soils over most of the county. No formations older than those of the Chesapeake group are visible. Along York River the St. Mary's and Yorktown formations outcrop, and at Yorktown, the type locality of the latter, and 3 miles up stream the bluffs are full of shells. Firm rock composed almost wholly of groundup shells makes the base of the bluff at Yorktown. The bottom of the Chesapeake group lies 180 feet below tide water in the northwestern corner of the county, and 550 feet below in the vicinity of Messick. The Pamunkey (Eocene) greensands and clays which underlie the Chesapeake formations are about 100 to 200 feet thick. Their base is approximately 400 to 800 feet below sea level. Upper Cretaceous beds undoubtedly underlie the Pamunkey, but their thickness is undetermined. The base of the Potomac (Lower Cretaceous) group lies possibly 1,200 feet below tide water in the northwestern part of the county and 2,300 feet below in the southeastern. The total thickness of the group in the eastern part of the county is fully 1,300 feet.

UNDERGROUND WATERS.

Distribution and quality.—The Columbia formations all carry more or less ground water, the depth to the water table, the yield to wells, and the quality of the water differ with the location of the wells. Wells on high ground, away from a terrace seep or creek valley, obtain soft water from the Sunderland or Wicomico sands within 20 feet of surface; other wells may go 40 feet to water. On the sands of the lowest terrace, east of Yorktown, wells are only 8 to 15 feet deep. The water is mostly soft but in places is iron-bearing, and under marshy tracts along tidal inlets is brackish. Dug wells on this terrace sometimes fill to the top. Where, near terrace scarps or stream valleys, the sands of the higher terraces are thin or contain little water, dug wells go through them and obtain ground water from the Yorktown or St. Mary's formation. This water is at many places hard or irony.

Artesian waters underlie the whole county. The sands in the Calvert formation of the Chesapeake group, in the Nanjemoy formation of the Pamunkey, and in still lower formations, have been tapped by wells on the north bank of York River, but, according to reported depths of wells, only those in the Chesapeake group have been developed in York County.

The supplies obtained are of good volume, heads range up to 30 feet, and the quality is generally satisfactory, the mineralization being greatest in the wells farthest down stream. A slight sulphur odor and a high proportion of bicarbonate of soda are the prevailing characteristics.

Springs.—Seeps and small springs from Columbia sands feed creeks that flow to York River, but are of little economic importance. Most of the larger springs flow from shell beds in the Chesapeake group; a few are used for household supply, and some of these can be used to better advantage by rams.

Wells.—There are many driven wells, and a few drilled wells less than 100 feet deep, on the low expanses of the Talbot terrace in the southeast end of the county; there are a few deep drilled wells along York River; elsewhere dug wells are used to reach underground waters. The relatively small number of drilled wells is a result of the small amount of low ground on the south bank of the river, most buildings being on high ground.

LOCAL SUPPLIES.

At Yorktown there were in 1906 but 3 dug wells; one on the bluff is 60 feet deep, the two others at lower elevation are 40 and 14 feet deep, respectively. All three go into shell beds and yield hard water. Cisterns are the usual source of domestic supply. A drilled well on the beach, 750 feet deep, yields 1 gallon per minute through a 1-inch pipe. The water is considered good.

At Messick a drilled well 60 feet deep found a flow of slightly irony water in sands lying either at the base of the Columbia or the top of the Chesapeake group. Particulars of the wells drilled along York River and its tributary creeks above Yorktown are summarized in table 5. They draw on sands tapped by wells across the river in Gloucester County.

One of the more notable wells is that of A. G. Harwood. This well is 400 feet deep and the flow has a head of over 20 feet.

Conditions reported from a number of places in York County that rely on dug wells are summarized in the following table:

Details of dug wells in York County.

Location	Depth of well *(Feet)*	Water bed	Quality of water
Grafton	16	Sand and marl	Hard
Grove	20–60	Shallow, sand; deep, marl.	Hard
Messick	8–15	Sand	Soft to brackish
Oaktree	25–50	Sand and marl	Soft to hard

Conclusions.—The artesian water prospects in York County vary from good to poor. In the western part of the county good flows can be obtained from Chesapeake, Pamunkey, and Potomac sands down to 1,000 feet or more below sea level, and the resources are practically inexhaustible. Farther east, as indicated by deep drilling in Warwick County to the south, and in Gloucester County to the north, the Calvert sands probably grow fine or clayey; they yield little water, and this contains a decidedly high proportion of solids in solution.

At Yorktown the same sand that is tapped at Gloucester Point yielded little water and the flows from the sands reached by the 750-foot well on the beach were disappointingly small. Stronger flows may perhaps be had by going deeper, but the water will not be any better. Heads will not be over 30 feet above tide and to raise the water to the top of the bluff pumping will be necessary.

On the low ground that begins 4 miles below Yorktown the same conditions probably prevail as in the east end of Gloucester County. Fair water, that will rise 2 or 3 feet above tide, may be found in the Yorktown formation by wells 80 to 100 feet deep; but little or no water will be found in the lower half of the Chesapeake, or in the Pamunkey. Deeper drilling will find flows in Upper Cretaceous or Potomac beds, but the water will be highly mineralized and at the wells farthest east decidedly saline. There is no reason to believe that better water will be found below 1,000 feet than above that depth. It probably will not pay to try to develop the sands in the Potomac group anywhere in the low ground below the scarp that runs across the peninsula from Newport News to 4 miles east of Yorktown.

TABULATED WELL DATA.

The following table (5) summarizes the information collected by correspondence and field work in regard to a large number of wells in the Tidewater region of Virginia. The list is very far from being complete, no attempt having been made to procure information regarding every well or even a majority of the wells at places where much drilling has been done, such as Colonial Beach, West Point, and Franklin. The depths, heads, and yields printed are in general correct, but some, because they were given from memory by owners, well drillers and others, are little better than guesses. Where figures reported by different persons varied, the more probable figures were taken. The authority for the items relating to each well is shown by the letters in the fifth column of the table, O standing for owner, D for driller, and M for miscellaneous—some third party—in many instances the local postmaster.

In tables 7, 8, 9, 10, and 11 are assembled available analyses and field assays of water from some of the wells listed in table 5. Information regarding the mineral constituents of the water from some of the springs mentioned is segregated in table 6.

Attention is called to the fact that some of the assays and analyses are more reliable than others, but the writer has not attempted to designate those that he considers the most carefully made. As regards the field assays, which are distinguished by (F) after the name of the analyst in the last column of each of the tables, they were made with the apparatus devised by the U. S. Geological Survey.[a] The determinations practicable with this apparatus differ widely in accuracy. The writer's experience is that the determination of chlorine can be made with most precision, and that the accuracy of the determinations of iron, calcium, sulphates, or total hardness may be seriously impaired by substances in solution interfering with the reaction that should normally take place.

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[a] Leighton, M. O., Field Assay of Water, U. S. Geol. Survey, W. S. Paper 151, 1905, pp. 27-75.

Results of all analyses and field assays are stated in parts per million and in ionic form. Thus, a water containing dilute solutions of bicarbonate of lime, bicarbonate of soda, sulphate of soda, sulphate of potash, and chloride of soda (common salt) has its composition indicated by so many parts per million of calcium (Ca), sodium (Na), potassium (K), bicarbonates (HCO_3), sulphates (SO_4), and chlorides (Cl).

TABLES OF ANALYSES OF WELL AND SPRING WATERS

TABLE 5—*Data of wells in Coastal Plain Province of Virginia.*

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide.	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
ACCOMAC						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Accomac	near	Benj. T. Melson	I. B. Clark	O	1904	24	50	2	50	15,35	50
Accomac	2 mi. E.	L. L. Tiffany		M	1899	2	100	2	100		
Belinda	½ mi. E.	M. E. Hall	I. B. Clark	O	1902	2	68	1½			
Belinda	½ mi. E.	M. E. Hall	J. W. T. Robertson	O	1899	6	84	2			
Belinda	Near	Hall & Rose	I. B. Clark	O	1902	2	68	1¼			
Belinda	½ mi. S.	J. D. Bull					80		40		
Bellehaven		C. S. Witham & Bros.		M			86	1½			
Bellehaven		D. R. Mister		O		5	120	1½	120		
Bellehaven		C. F. Chase		M	1901	2	60	1½		6-16	
Bloxom		Guilford Church	W. McK. Taylor	M			105	1½			
Boggs	near	H. Battail	I. B. Clark	O	1906	10	150	1½	150		130
Boggs	near	F. C. Taylor	I. B. Clark	O	1904	8	150	1½	150	75	60
Cashville		E. M. Boggs	J. W. T. Robertson	O	1902	8	101	1½	101		100
Cashville		H. R. Boggs	J. W. T. Robertson	O	1902	6	97	1½	97		97
Cashville		H. R. Boggs & Bro.	J. W. T. Robertson	O	1904	6	90	1½			
Cashville		Broadway Baptist Church	J. W. T. Robertson	M	1904	12	110	1½	110		110
Cashville		S. Crockett	Bailey East	D		2	112	1½	112		
Cashville		W. S. Finney	J. W. T. Robertson	O	1902	7	100	1½	100		100
Cashville		T. W. Scott	J. W. T. Robertson	O	1902	2	97	1½	97		
Cashville		T. W. Scott	J. W. T. Robertson	O	1904	2	87	1½	87		
Cashville		T. W. Scott	J. W. T. Robertson	O	1906	2	90	1½	90		
Chesconnessex		Bailey East	Bailey East	O	1905	1½	137	1½	137	40,75,100	
Chesconnessex		J. L. Savage	I. B. Clark	D	1903	5	103	1½			
Chesconnessex		F. Jenkins	J. W. T. Robertson	M	1901	1	90	1½	90		
Chincoteague Is.		United States			1885?	3	135	2			
Chincoteague Is.		James Williams	James Williams		1890	5	70	1½			
Craddockville		Thos. J. Custis	I. B. Clark	O	1902	2½	62	1½	60	12,22	60
Craddockville		G. B. Mason	J. W. T. Robertson	O	1902	6	60	2	60		30
Craddockville		L. J. Melson	J. W. T. Robertson	O	1900	4	140	1½	140		
Craddockville		L. J. Melson	I. B. Clark	D	1904	7½	175	1½	173		140
Davis Wharf		S. J. Bull	J. W. T. Robertson		1902		105	2½			165
Finney	near	Susan A. Finney		M	1899	2	90	1½	90		
Finney		W. F. Rogers	J. W. T. Robertson	O	1901	1½	83	1½	83		83
Finney		Mears	I. B. Clark	D	1906	1½	80	1½			83
Finney		S. F. Rogers									
Fox Island		Wm. Ellinger	J. W. T. Robertson	O	1903	0	76	1½			
Franklin City	near	Wm. B. Powell	F. T. Mumford		1904	60	73	1½	70	36,38	
Gratons	¼ mi. N. E.	W. A. Bloxom	F. T. Mumford	O	1904	11	151	1½	151	80	
Gratons		J. W. Weasells	F. T. Mumford	O	1904	10	160	1½	160	85	
Gratons	near	E. D. Groton	F. T. Mumford		1904	10	100	1½	100	75	
Harborton	near	J. W. Adams	J. W. Adams	D	1905	8	149	1½			120
Harborton	near	W. H. B. Custis	J. W. Adams	D	1900	8	144	1½			55
Harborton	near	Allen & Sennen		M	1882	6	148	1½			
Harborton	near	S. K. Martin	I. B. Clark	D	1903	10½	137	1½	137	35, 128	94
Harborton	near	Martin & Mason Co.	J. W. T. Robertson	O	1903	2	140	1½	140	35, 128	100
Harborton		Geo. Moore	J. W. Adams	D	1906	8	174	1½			60
Harborton		W. K. Reed	J. W. Adams	D	1905	8	139	1½	139		55
Harborton		J. W. Walker	J. W. Adams	D	1905	8	145	1½	145		55
Hallwood		Wesley Bloxom	J. W. Adams	D	1904	5	150				
Hallwood		Wm. T. Bloxom	J. W. T. Robertson	D	1906	7	103				
Hallwood	near	James A. Hall	I. B. Clark		1903	10	186	1½	20	110, 150	
Hallwood	near	New York, Philadelphia & Norfolk R. R.				10	35-60				
Hallwood		James W. Tailor			1902	10	140	1½			
Hopkins		John Barnes	J. W. T. Robertson				125	1½	125		

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
Gray sand	Columbia	+17		5	58	Soft	Domestic and stock
	Columbia (?)	+10	1¼		59		Drinking and stock
Sand and shells	Columbia	+10		2		Hard, brackish, irony	Washing oysters
	Columbia (?)	+2					Abandoned
Sand and shells	Columbia	0				Hard, brackish, irony	Washing oysters
	Columbia	flows				Soft	Domestic
	Columbia						Domestic
	Chesapeake (?)	+5					Domestic and canning factory
Sand	Columbia	+4					Drinking
	Chesapeake (?)						Drinking
	Chesapeake (?)	+8				Soft	Domestic
Sand	Chesapeake (?)	+8	5			Soft	Domestic
	Chesapeake (?)	+5		8	60	Slightly sulphur and iron-bearing	Domestic
	Chesapeake (?)	+4		8		Slightly sulphur and iron-bearing	Domestic and stock
	Columbia (?)						Stock
	Chesapeake (?)			10	59	Slightly sulphur and iron-bearing	Domestic
	Chesapeake (?)	+1					
	Chesapeake (?)	+4		8	60	Slightly sulphur and iron-bearing	Domestic
Sand	Chesapeake (?)	+2	¼-1				Domestic
	Columbia (?)	+3	2				Domestic
	Columbia (?)						Domestic
	Chesapeake	0				Irony	Domestic and stock
	Chesapeake						Domestic
	Chesapeake	+2	1				Domestic
	Chesapeake (?)						No flow, abandoned
	Columbia						No flow, abandoned
Gravel	Columbia	+5	3				Domestic and stock
	Columbia	+1½	3				Domestic and stock
Shelly rock	Chesapeake (?)	+6	1			Soft	Domestic and stock
	Chesapeake (?)	+8?					
Sand	Chesapeake (?)						
			6		59	Slightly sulphur-bearing	Domestic and stock
	Columbia (?)	+3	4		60	Slightly sulphur-bearing	Domestic and stock
Gravel	Columbia (?)	+2	4				Domestic and stock
Gravel	Columbia (?)						
Sand and gravel	Columbia (?)	0		5		Hard, salt and iron-bearing	Washing oysters
	Columbia						Domestic
Sand and shells	Chesapeake (?)			15		Soft	Domestic and stock
Rock at 85	Columbia (?)	+5				Soft	Domestic and stock
Sand and shells	Columbia (?)	+6		15		Soft	Domestic and stock
Sand	Chesapeake (?)	+8					Domestic
Sand	Chesapeake (?)	+8					Domestic
	Chesapeake (?)	+8	4-5		62		Boiler
Gravel	Chesapeake (?)	+12	1			Slightly sulphur-bearing	Domestic and stock
Gravel	Chesapeake (?)	+8	5			Slightly sulphur-bearing	
	Chesapeake (?)	+8½					Domestic
	Chesapeake (?)	+8½					Domestic
	Chesapeake (?)						Domestic
Shells	Chesapeake (?)	+1		15			Domestic and stock
Shells	Chesapeake (?)	+3½		15			Household
Gravel	Chesapeake (?)					Irony	Not used
	Columbia						Locomotives
	Chesapeake (?)					Irony	Not used
Rock at 63 ft.	Chesapeake (?)	flows				Soft	Domestic and stock

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
ACCOMAC—Cont.						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Hopkins	....	Oliver Barnes	J. W. T. Robertson	O	1897	.....	108	2	.....	....	70
Hopkins	....	J. S. Gordy	J. W. T. Robertson	O	1902	.....	119½	2	119½	60	116
Hopkins	½mi.S.E.	A. J. Lewis and W. J. Russell	J. W. T. Robertson	O	1904	4	64	1½	64	15	46
Hopkins	....	Frank Lewis	J. W. T. Robertson	D	1903	2½	175	1½	170	115-170	120
Hopkins	....	H. A. Lewis	W. McK. Taylor	O	1901	1	95	1½	95	....	75
Justisville	near	J. R. Ewell	W. McK. Taylor	M	.....	.....	130	1½	.....	....	....
Justisville	....	J. T. Willett	W. McK. Taylor	O	1906	.....	68	1½	65	....	65
Leemont	2 mi. S.E.	J. H. Hopkins	J. W. T. Robertson	O	1897	5	100	1½	100	....	....
Leemont	....	H. A. Lewis	W. McK. Taylor	O	1899	8	122	2	122	....	....
Locustville	....	G. L. Dougherty	I. B. Clark	D	1905	6	104	1½	104	....	....
Locustville	....	B. T. Gunter	J. W. T. Robertson	O	1899	6	140	2	122	....	122
Mappsville	....	J. W. Tailor	I. B. Clark	D	1904	40	70	1½	70	16, 32	....
Marsh Market	near	Jas. A. Hall (Two wells)	I. B. Clark	D	1904	.....	55-72	1½	.....	....	....
Marsh Market	near	Jas. A. Hall (Two wells)	J. W. T. Robertson	O	1906	5	92	2	.....	....	....
Mearsville	2mi.N.W.	J. R. Hart	W. McK. Taylor	M	1901	3	85	2	85	25, 40	....
Mearsville	....	S. Rue	J. W. T. Robertson	D	1906	6	150	2	.....	....	....
Mearsville	....	W. J. Somers	I. B. Clark	D	1904	6½	117	1½	117	80	100
Mandua	....	Richard Cutter	J. W. Adams	D	1906	4	82	1½	.....	....	80
Mandua	....	H. Guy	J. W. T. Robertson	D	1905	2	80	2	.....	....	80
Mandua	....	John B. Henderson	....	O	1902	8	153	1½	153	....	150
Mandua	....	Dr. A. T. L. Kusian	J. W. T. Robertson	O	1902	2	74	2	70	8	70
Mandua	....	John O. Stevens	J. W. Adams	D	1906	.....	140	1½	140	92	100
New Church	near	J. E. Johnson	I. B. Clark	O	1905	24	125	2	125	35,40,82	125
Onancock	near	Town	C. S. York & F. A. Merrill	D	1895	8	16-50	2½	50	....	....
Onancock	near	Town	B. T. Parker	M	1890	10	350	....	.....	....	....
Onancock	near	Town	J. H. K. Shanahan	M	1894	10	486	....	140	140	....
Onancock	near	H. L. Crockett	J. W. T. Robertson	O	1899	2½	109	1½	104	94	....
Onancock	near	W. B. Pitts	J. W. T. Robertson	O	1900	4	130	2	.....	....	....
Onancock	near	M. L. Hurst	J. W. T. Robertson	O	1900	3	36	1½	35	9	30
Onley	near	Joseph Bull	J. W. T. Robertson	O	1905	15	51	....	.....	....	....
Onley	near	J. W. Rodgers	I. B. Clark	D	1905	10	53	1½	53	10, 25	....
Parksley	3 mi. W.	W. McK. Taylor	W. McK. Taylor	O	1904	6½	135	1½	135	10,30,60	135
Pungoteague	....	S. W. Ames	I. B. Clark	O	1903	18	210	1½	204	20,30,55	204
Pungoteague	1 mi. N.	T. J. Custis	J. W. T. Robertson	O	1902	.....	140	1½	140	....	140
Pungoteague	....	S. D. Taylor	J. W. T. Robertson	O	1904	20	110	1½	63	....	63
Pungoteague	....	G. B. Mason	J. W. T. Robertson	O	1899	.....	60	2	60	10	....
Pungoteague	....	J. S. Waterfield	J. W. T. Robertson	O	1902	4½	158	1½	158	150	158
Pungoteague	....	J. S. Waterfield	J. W. T. Robertson	..	1902	.....	140	1½	.....	....	....
Quinby	¾ mi. W.	Machipongo Bridge Co.	J. W. T. Robertson	O	1904	5	87	1½	87	16, 32	....
Sanford	near	Frank McKay	J. W. T. Robertson	O	1898	5	76	2	.....	....	....
Sanford	....	J. J. Furniss	....	.....	.....	.....	82	2½	.....	....	....
Saxis	near	J. T. Weaver	I. B. Clark	O	1904	4	112	1½	110	73	112
Sanford	....	Baltimore, Chesapeake & Alantic Steamboat Company	I. B. Clark	D	1903	4	95	1½	.....	....	....
Tangier Island	....	J. J. Daly	J. W. T. Robertson	D	1905	3	250	2	141	8	160

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
	Chesapeake (?)						Domestic and stock
Sand and rock at 90 ft.	Chesapeake (?)	flows	2				Domestic and stock
Gravel	Columbia	+1½		25		Soft	Domestic and stock
	Chesapeake (?)	+4	2				Domestic and stock
	Columbia	+2	½			Sulphur	Domestic and stock
	Chesapeake (?)					Soft	
	Chesapeake (?)			5			Domestic and stock
Rock at 90 ft. gravel	Chesapeake (?)	+5	2½			Soft, slightly sulphur and iron-bearing	Domestic and stock
Sand	Chesapeake (?)	+6½				Slight sulphur	Domestic
	Chesapeake (?)	+7	1½				Domestic
Sand	Chesapeake (?)	+3½		12			Domestic
Sand	Columbia	+5					Domestic and stock
	Columbia	+5					Domestic and stock
	Columbia	+4		5			Boiler
Rock at 40 ft. Sand	Columbia	+1½		8		Soft, irony	Household and stock
	Columbia (?)						
Sand	Columbia	+8	1½				Household and stock
	Columbia	+8	1½				Domestic and stock
	Columbia	+2½					
	Chesapeake (?)	+7		5	58		Domestic and stock
Rock	Columbia	+4	1¾		59	Soft, slightly iron-bearing	Drinking and stock
	Columbia (?)						Domestic and stock
	Columbia (?)	+15		5			Domestic
Sand	Columbia					Hard	Town supply
	Chesepeake						No flow, abandoned
	Chesapeake			5		Sulphur-bearing	No water below 140 feet, abandoned
Sand	Columbia	+3	1				
Sand	Columbia		4			Soft	Domestic and stock
	Columbia	+5	2				Domestic and stock
	Columbia						
	Columbia	+8		5			Domestic
Sand	Columbia	+7				Soft	Domestic and stock
	Chesapeake (?)	+8			59	Soft	Domestic and stock
	Columbia (?)						Domestic and stock
	Columbia	+10		6	60		Domestic and stock
	Columbia	flows	3				Domestic and stock
Sand and gravel	Chesapeake (?)		18(?)				Domestic and stock
	Columbia (?)						Domestic and stock
Sand	Columbia	+7	1½	25		Irony	Domestic
Sand and shells	Columbia	±0					Domestic and stock
	Columbia			5			Domestic and stock
Sand and gravel	Columbia	±0		5		Hard	Domestic and stock
	Columbia	±0					
Fine sand	Chesapeake (?)	±0		5		Salty	No flow, abandoned

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
						Ft.	Ft.	In.	Ft.	Ft.	Ft.
ALEXANDRIA											
Addison		Standard Brick Co.			1895		140				
Addison		New Washington Pressed Brick Co.		O	1898		131				
Alexandria		Southern Railway					370±				
Alexandria		O. M. Adams		O	1898	200	68	48	64		
Alexandria		Alexandria Fertilizer and Chemical Co.	R. L. Thomas	O	1906	10	445	8–6	225	350	
Alexandria		Belle Pre Bottle Co.		O	1907	40	185	6	175		
Alexandria		People's Ice Co.		O	1894	82	401	8–6			
Alexandria		Robert Portner Brewing Co.	W. C. Miller	O	1888	38	430	8	410	61	370
Alexandria		Robert Portner Brewing Co.		O	1902	35	370				
				O	1903	38	392	8	370	61	
Alexandria		Washington, Alexandria & Mount Vernon Ry.	Washington Well Drilling Co.	M	1904	8	135	6	60		
		G. N. Saegmuller	W. C. Miller	D			555		80		
Ballston		Livingston Heights Syndicate					160	6	160	100	
Ballston		Admiral Weaver		O		300	60	24	50		
Fostoria		A. M. Lathrop	W. C. Miller	D		172					
Weddebourne		R. W. Walter		O		480	130	6	126	30	
CAROLINE											
Etta		O. M. Harris	C. M. Gouldman		1905	16	175	1½	173		12
Mossneck		A. B. Lewis	Geo. Heflin	D		30	169	2	167	100	167
Port Royal		J. D. Farish	C. M. Gouldman	O	1905	35	243	2			
Port Royal		C. M. Gouldman	C. M. Gouldman	M	1905	23	200	1½	200	175	40
Port Royal		Mrs. Eliza T. Pratt		M		25	200?	2	200?		
Port Royal		Town of Port Royal	Hammer & Hall	M	1905	4	235	1½	235		
CHARLES CITY											
Roxbury	near	T. L. Walker	Sydnor Pump & Well Co.	O	1902	40	280	2-1	280	70	80
Shirley	near	H. S. Saunders	H. E. Shimp	D	1908		355	2			
Sturgeon Point		J. J. Truax	Sherman Jones	O	1895	50	60	72	40		
Westover	1¼mi.E.	Wm. M. Ramsay	Sydnor Pump & Well Co.	O	1901	15	139	10	134	139	
Willcox Wharf		E. A. Saunders, Jr., and Son (6 wells)		O	1907	2–24	168–184	2	168–184		
DINWIDDIE											
Petersburg	¼mi.E.	J. B. Worth Co.	A. P. Jerguson	D	1892	5	600	8			
ELIZABETH CITY											
Fort Monroe	near	Chamberlain Hotel	Thos. B. Harper	O		4	945	4			
Fort Monroe	near	United States		M		3	907				
Fort Monroe	near	United States		M	1896	3	2,254	15–6		many	220
North End Point			R. H. Milligan	D	1896	4	1,085	3			
North End Point			J. S. Darling	M	1887	2	1,172	6(?)			

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
Sand	Patuxent	+5		75		Soft	Boiler
	Patuxent					Soft	Boiler
							Abandoned
Sand and gravel		130				Soft	Domestic and stock
Sand and gravel	Patuxent	-5		60		Acid and iron-bearing	
	Patuxent			65			Glass works
	Patuxent	+3		300		Soft	Ice manufacture, table water
Sand	Patuxent			90	62	Soft	Brewing, boilers and drinking
	Patuxent			80 200			Brewing, boilers and drinking
		+23	3		61		Drinking
Granite				2			
				2			
Granite				15		Excellent	
Granite				13			
		+27	¼		63		Household and stock
Black clay	Patuxent (?)		¼				
	Pamunkey (?)						Domestic
Dark sand	Pamunkey (?)	+24				Soft	Domestic and stock
	Pamunkey (?)					Soft	Domestic
	Pamunkey (?)	+10	10		61	Soft	Domestic and stock
Gravel	Potomac			10	61	Soft, slightly sulphur	Boiler, domestic and stock
							No flow; not used
Clay	Chesapeake	+10				Soft	Domestic and stock
Fine black sand.	Pamunkey	+5		70		Soft	Domestic and stock
	Pamunkey	+32	6-80				Domestic and stock
Granite				100		Soft	Boiler, ice manufacture
	UpperCretaceous	+14	10			Saline, ferruginous	Flushing
						Saline	Never used
Sand	Several					Saline	Never used
							Never used; no flow
							Never used; no flow

TABLE 5 (*Continued*)—*Data of wells in Coastal Plain Province of Virginia.*

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
ESSEX						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Bowlers Wharf..	near	Claybrook & Neale Packing Co.	L. Rude	O	1898	5	165	1½	165	......	16
Bowlers Wharf..	near	Garrett & Hunt..........	Garrett & Hunt.....	O	1903	5	167	2	167	130	151
Bowlers Wharf..	near	Garrett & Hunt..........	H. L. Skimp........	O	1896	5	185	....	.....	130	....
Bowlers Wharf..	near	Garrett & Hunt..........	....	M	......	8	182	1½	.....	....	....
Bowlers Wharf..	near	C. P. Garrett..........	J. H. Taylor........	O	1902	10	185	1½	185	170	....
Bowlers Wharf..	½ml. S.	I. W. Hunt..............	I. W. Hunt..........	O	1898	19	182	1½	.....	....	....
Blowers Wharf..	1 ml. N.	Frank Hutchinson.......	J. H. Taylor........	O	1903	4	172	1½	170	....	160
Blowers Wharf..	1 ml. N.	R. C. Kaighn...........	J. H. Taylor........	O	1902	4	168	1½	165	....	168
Bowlers Wharf..	near	R. G. Neal..............	W. S. Johnson......	O	1888	9	130	1½	.....	....	....
Bowlers Wharf..	½ml. S.	A. D. Pitts..............	J. H. Taylor........	M	1905	.....	240	1½	.....	....	182
Bowlers Wharf..	near	Wm. J. Rice............	W. S. Johnson......	O	1888	7	260	1½	.....	....	....
Butylo	2ml.N.W.	I. W. Hunt..............	I. W. Hunt..........	O	1898	5	221	1½	.....	....	80
Caret	....	J. P. Taliaferro........	Hammell & Hale.....	M	1903	30	300	1½	290	....	....
Center Cross ...	2ml. S. E.	C. F. Kriete.............	Lyle & Rude.........	O	1891	80?	350	1½	.....	....	300
Center Cross ...	2ml. S. E.	C. F. Kriete.............	W. S. Johnson......	O	1895	4	190	1½	.....	....	180
Center Cross ...	2ml. S. E.	C. F. Kriete.............	L. Rude	O	1903	6	195	1½	.....	....	190
Champlain	....	Joseph Baker...........	....	..	1903	33	75	1	.....	....	....
Chance	....	J. H. C. Beverly.......	L. Rude	O	1898	40	380	2	380	250	....
Chance	....	J. H. C. Beverly.......	L. Rude	M	......	20	260	....	.....	....	....
Chance	....	Mrs. M. S. Sale........	L. Rude	..	1897	30	180	2	180	none	....
Dunnsville	....	J. E. Kriete.............	Geo. Beazeley	O	1888	7	300	1½	.....	....	186
Dunnsville	....	J. E. Kriete.............	Chas. Ramsam.......	O	1903	100	60	36	.....	....	....
Loretto	....	H. L. Baylor............	L. Rude	M	1888	-7	160	....	.....	....	....
Loretto	....	W. C. Dickinson........	L. Rude	O	1900	38	198	1½	198	....	....
Tappahannock ..	near	G. N. Anderson.........	....	M	......	18	274	1½	.....	....	....
Tappahannock ..	near	T. E. Blakey............	O. D. Hale..........	O	1906	19	272	1½	.....	....	65
Tappahannock ..	near	Wm. V. A. Andrews....	Hammell & Hale.....	M	1902	20	270	1½	.....	....	....
....	....	John Bradley	H. E. Shimp.........	M	1902	10	278	1½	.....	....	....
Tappahannock ..	¼ml. E.	B. B. Brochenborough..	Geo. Beazeley.......	O	1901	18	272	3-2	272	....	272
Tappahannock ..	1ml.N.W.	B. B. Brochenborough..	Hammell & Hale.....	O	1905	27	273	1½	270	....	....
Tappahannock ..	1ml.N.W.	B. B. Brochenborough..	Hammell & Hale.....	O	......	15	270	....	.....	....	....
Tappahannock ..	near	R. T. Cauthorn..........	W. J. Reamey.......	O	1895	18	275	1½	.....	....	275
Tappahannock ..	near	G. F. Croxton...........	Hammell & Hale.....	O	1904	20	268	1½–¾	.....	....	268
Tappahannock ..	near	G. W. Daingerfield......	O. D. Hale..........	O	1906	21	275	1½	2	....	65
Tappahannock ..	¼ml. E.	Donaldson & Schultz....	Hammell & Hale.....	M	1900	4	256	1½	256	125	60
Tappahannock ..	near	J. W. Faulconer.........	Hammell & Hale.....	O	1903	15	275	¾	275	150	275
Tappahannock ..	....	J. H. Henley............	Hammell & Hale.....	O	1898	16	275	1½	275	....	275
Tappahannock ..	near	T. C. McDaniel..........	....	O	1903	17	282	1½	278	....	278
Tappahannock ..	near	L. E. Munford Banking Co.	Hammell & Hale.....	O	1904	18	275	1½	275	150	....
Tappahannock ..	2ml. W.	D. Passagaluppi	H. E. Shimp.........	O	1903	8	275	1½	.....	....	....
Tappahannock ..	....	W. B. Robinson.........	Hammell & Hale.....	O	1904	.....	277	2	277	60–275	....
Tappahannock ..	near	G. R. Scott.............	....	..	......	18	275	1½	.....	....	....

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
Sand	Calvert	+12	49		61½	Soft	Canning factory
Sand	Calvert	+15	30		63	Soft	Drinking and washing oysters
	Calvert	+15				Soft	Not used
	Calvert		5			Soft	
	Calvert	+15	17				Household
	Calvert	+19	2				
	Calvert	+10	7½		61½		Household and stock
	Calvert	+10	3				Household and stock
	Calvert		⅛				Household and stock
	Pamunkey	+14	6		61¼		Household
	Pamunkey	+12	7		61		Household
	Calvert	+15	20				Household
	Pamunkey	+31	⅛			Soft	Drinking
		+30					Not used, no flow
	Calvert	+12	6		61	Soft	Stock
	Calvert	+30	32		62	Soft	Canning factory
	Calvert					Soft	
White sand	Potomac	+43	2			Soft	Domestic
	Pamunkey						
White sand	Pamunkey	+35	2½			Soft, iron and sulphur	Domestic
Sand	Pamunkey		16			Soft	Stock
	Calvert (?)						
	Pamunkey		22				
	Pamunkey		5				Household
Sand	Pamunkey		½		60		Household
Sand	Pamunkey	+30	3		61	Soft	Domestic and public
Sand	Pamunkey		3			Soft	Household
Sand	Pamunkey						Household and stock
	Pamunkey	+31	2	2	62	Soft	Domestic
	Pamunkey	+35	2⅙			Soft	Domestic
	Pamunkey					Soft	Stock
	Pamunkey	+31	2		61½	Soft	Domestic
Sand	Pamunkey	+20	1½			Soft	Domestic and stock
Sand	Pamunkey	+25	1¾		61		
Sand	Pamunkey	+20	12-5½		62½		Pickle house
Sand	Pamunkey	+18	2			Soft	Household and stock
Sand	Pamunkey	+16	1			Soft	Hotel
Sand	Pamunkey	+20	1¾		61	Soft	Household
Sand	Pamunkey	20					Domestic and stock
Sand	Pamunkey						Domestic and stock
Fine sand	Pamunkey	+20	1-3			Soft	Domestic and stock
Sand	Pamunkey						Canning factory and domestic

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Essex—Cont.											
Tappahannock	near	H. Southworth	Hammell & Hale	O	1903	19	275	1½	....	....	....
Tappahannock	near	R. C. Phillips & Co	Geo. Beazeley	O	1892	15	275	1½	....	....	100
Tappahannock	near	Mrs. C. N. Temple	Hammell & Hale	O	1904	....	177	3	....	70, 112 156	....
Tappahannock	near	E. N. Ware	H. E. Shimp	O	1898	18	280	1½	....	....	....
Tappahannock	near	T. R. B. Wright	Hammell & Hale	O	1904	18	277	1½	....	....	....
Ware's Wharf	1mi.N.W.	R. W. Eubank	Wm. S. Johnson	O	1888	2	190	1½	190	....	....
Ware's Wharf	near	H. H. Ware	L. Rude	O	1899	5	180	1½	170	....	....
Ware's Wharf	near	R. L. Ware Estate	Wm. S. Johnson	O	1890	+3	205	1½	185	140	....
Ware's Wharf	¾mi.N.W	R. L. Ware, Jr.	L. Rude	O	1899	12	180	1½	170	100	....
Ware's Wharf	near	W. L. Ware	Geo. C. Taylor	M	1895	14	170	1½	165	....	80
Fairfax											
Accotink		C. Lukens	——Bushong	M	1887	50	75	5	69	50	13
Accotink		J. P. H. Mason		O	1866	180	91	56	88	45	....
Clifton Station		W. H. Edwards		O	1895	....	....	....	100	....	....
Gunston			L. W. Shepard	D	....	....	560	....	264	....	....
Falls Church		Henry Birge	——Baker	M	1897	....	80	6	....	....	....
Fort Hunt			J. C. Miller	O	1891	30	165	6	....	....	....
Fort Hunt		United States	J. C. Miller	D	1899	40	212	8	202	....	....
Mount Vernon		Mount Vernon Co.	J. H. K. Shannahan	O	....	4	525	6	340	525	....
Riverside		Riverside Brick Co.		O	....	....	125	6	....	....	....
Woodbridge			Sydnor Pump & Well Co.	D	....	....	600	6	150	....	....
Gloucester											
Achilles	near	B. A. Rowe		O	1903	6	50	2	....	....	....
Achilles	near	B. A. Rowe	H. E. Shimp	O	1903	6	615	2	450	600	288
Achilles	near	Union Church	H. E. Shimp	D	1905	5	450	2	400	....	400
Allmondsville	near	W. W. Allmond	J. V. Bray	O	1888	6	270	1½	270	150	....
Allmondsville	near	W. W. Allmond	H. E. Shimp	D	1907	20	400(?)	2–1	400	200	400
Bridges	3 mi. W.	G. E. Brown						....	585?	....	....
Bridges	3 mi.S.W.	James Brown	H. E. Shimp	D	1904	5	610	2–1	60 535	....	....
Bridges	2 mi. S.	Chas. Catlett	H. E. Shimp	O	1908	3	65	1½	....	....	....
Bridges	2 mi. S.	Chas. Catlett	H. E. Shimp	O	1903	3	128	1½	....	....	....
Bridges	2 mi. S.	Chas. Catlett	H. E. Shimp	O	1903	3	440	2–1	....	....	....
Bridges	3 mi.S.W.	L. M. Kemp	H. E. Shimp	D	1905	0	510	1½	500	300	....
Bridges		Joshua Minor		..	1904	....	550	....	....	....	....
Bridges	2 mi.S.W.	Dr. Oliver	H. E. Shimp	D	1904	....	365	2	....	....	....
Cappahosic	⅛ mi. E.	Sidney Monsell	H. E. Shimp	O	1901	33	416	4– 1½	416	375	290
Claybank	at	L. M. Newcomb	H. E. Shimp & S. H. Fetterholf	O	1905	6	367	1½	365	none	....
Freeport	near	E. C. Farinholt	H. E. Shimp	O	1901	2	330	1½	330	....	16 330
Freeport	near	R. H. Farinholt	H. E. Shimp	O	1901	10	338	1½	330	....	290
Glass		L. Hall	H. E. Shimp	D	1904	....	615	2–1	....	....	....
Gloucester	near	W. E. Carr	Geo. Hughes	O	1885	70	350±	1½	350?	....	....
Gloucester	near	W. E. Carr		O	1895	70	180	1½	59	....	....

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
nd	Pamunkey		1¾		61½		Domestic
nd	Pamunkey	+29	1¼			Soft	
nd	Pamunkey	+10	1½			Soft	Household and stock
	Pamunkey						Domestic
	Pamunkey		3		62		Domestic
rous rock	Calvert	+5			61	Soft	Domestic and stock
	Calvert	+14	5½		61½	Soft	Domestic
ack sand	Calvert	+14	2–1		61	Soft	Domestic and stock
	Calvert	+14			61½	Soft	Domestic
ck	Calvert	+16	½		61½		Domestic
avel		+40		16	56(?)	Hard	Stock and drinking
e clay		+92				Soft	Domestic and stock
ft slate		-0				Soft	Domestic and stock
							Domestic
ite sand	Patuxent			10			Domestic, stock
		+23		53		Soft	Supplies fort
nd	Patuxent	+1		30			Drinking
	Columbia	±0		10		Soft	Boiler
nd	UpperCretaceous	+16	1¼		61½	Slightly saline, sulphur	Domestic
ck	Pamunkey (?)	+10	¼		60	Slightly saline, sulphur	Drinking
ack sand	Calvert	+15	3		63	Soft, sulphur	Drinking
ck	Pamunkey		2½			Soft	
							Washing oysters, medicinal
							Little water below 60 ft. Not used
	St. Marys	+1½				Soft	Drinking
	St. Marys						
	Calvert					Soft, sulphur	Little used
	Pamunkey	+32					
	Pamunkey				65(?)		
	Calvert (?)	+39					
ne, dark green rock	Pamunkey	+42	5		65	Soft	Domestic, stock, boiler
	Calvert	+30	1½				Household and stock
	Calvert	+16	2		63		Household and stock
	Calvert		½		63		Household and stock
	UpperCretaceous						
ack sand		+40					No flow, abandoned
		+40?					No flow, abandoned

TABLE 5 (*Continued*)—*Data of wells in Coastal Plain Province of Virginia.*

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
GLOUCESTER—Cont.						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Gloucester Point	near	Chesapeake S. S. Co., Gloucester County	H. E. Shimp	D	1903	6	694	2½ -1	690	none	[illegible] 694
New Upton	....	R. J. Bristow	H. E. Shimp	O	1901	8	415	¾	415	8-42 235	....
Pinetta	....	....	....	..	....	....	215	1½	....	....	....
Pinetta	....	E. H. Scanlan	....	..	1903	....	350	....	350	....	....
Selden	S. W.	Joseph Bryant	Sydnor Pump & Well Co.	O	1905	6	1,020	8	....	....	....
Selden	....	Joseph Bryant	....	..	1900	7	110	6	....	....	....
Selden	....	Joseph Bryant	D. E. Miller and H. E. Shimp	D	1905	7	981	6-2	850	....	[illegible]
Selden	S. W.	Alfred W. Withers	Sydnor Pump & Well Co.	O	1901	6	716	6-4	716	....	....
Sassafras	3 mi. S.	B. T. Weaver	H. E. Shimp	O	1904	4	336	1½	330	....	....
Severn	near	J. M. Shackelford	W. D. Diggs	O	1902	5	610	2	585	610	575
Signpine	3mi. S.W.	R. C. Coleman	....	O	1886	3½	211	1½	211 180	13 33 160 196	....
Signpine	2 mi. N.	E. H. Scanlan	H. E. Shimp	O	1903	25	350	2	....	....	....
Signpine	3½ mi. E.	Peter Van Name	—Thompson	O	....	5	180	2	....	....	....
Wareneck	2 mi. E.	W. A. Jones	....	M	....	8	300	1¼	....	....	....
GREENESVILLE											
Emporia	....	Town	Sydnor Pump & Well Co.	M	1906	....	600	8	470	62 370	[illegible]
HANOVER											
Ashland	¼ N.	Randolph-Macon College	....	O	....	....	140	2	....	....	....
Ashland	⅛ N.	Randolph-Macon College	....	O	....	....	100	4	....	....	....
Ashland	....	G. W. M. Taylor (Henry Clay Inn)	Sydnor Pump & Well Co.	M	1906	....	365	8	....	....	....
Ashland	....	Ashland G. S. & W. Co.	....	..	....	....	374	10	....	....	....
Doswell	near	Richmond, Fredericksburg & Potomac R. R.	....	..	....	....	250 327	6	....	....	....
HENRICO											
Catman	....	Curles Neck Farm	F. M. Gould	..	1900	30	926	8	....	32 150	211
ISLE OF WIGHT											
Benns Church	....	Heath	....	..	....	....	250	....	....	....	....
Ivor	....	Shaw Lumber Co.	....	O	1907	60	190	6	185	....	....
Shoal Bay	3 mi. E.	J. A. Morgart	J. P. Ginder	O	1900	32	383	2	383	none	[illegible]
Shoal Bay	3 mi. E.	J. P. Tower	W. Wilson	M	1907	32	380	1½	....	....	[illegible]
Shoal Bay	½ mi. N.	W. D. Turner	....	M	1906	18	226	2½	220	none	[illegible]
Smithfield	....	Smithfield Mineral Water Co.	....	O	....	....	300	....	....	....	....
Zuni	near S.	J. M. Darden	J. T. Moore	O	1895	25	150+	2	....	....	....
Zuni	near	Town of Zuni	J. T. Moore	D	1895	....	162	2	....	....	....
Zuni	5 mi. E.	Mt. Carmel Christian Ch.	J. T. Moore	D	....	35(?)	190	2	....	....	....

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
ite rock"	Upper cretaceous	+20	2		64+	Soft, sulphur	Drinking, household, etc.
w rock	Calvert	+16	¼			Soft	Domestic and stock
	Calvert (?)	+4					
	Pamunkey						
							No flow, abandoned
	St. Marys	+8½		10		Hard	Drinking
	UpperCretaceous	+5	½			Saline, sulphur	
l	UpperCretaceous	+32	52		70	Saline, sulphur, irony	Washing, bathing
green sand	Pamunkey	+20	1½	40		Soft	Domestic and stock
	Pamunkey (?)	+16	⅛		65	Soft	Drinking
k at 196 ft. l	Calvert	+8	1			Soft, sulphur	Household and stock
us rock	Pamunkey	+30	1½			Soft	Domestic
	Calvert	+15	½			Soft, sulphur	Household
	Calvert						Stock
ite		+20		100		Irony	Abandoned
stone	Newark						Abandoned
stone	Newark						Not used
	Newark						Hotel supply
				45 85			Public supply
	Newark	+30?					Drilled for locomotive supply; abandoned
ite		+4		100	62	Soft	Domestic and stock
	St. Marys						
	St. Marys (?)						Domestic and boiler
k and white nd	Calvert	+36	1/16		58	Soft, alkaline	Hotel, medicinal
k and white nd	Calvert						
k and white nd	St. Marys	+30	1/16			Alkaline	Drinking, medicinal
	St. Marys	flows				Soft, alkaline	Drinking, medicinal
	St. Marys	32(?)	2			Soft	Drinking
	St. Marys		1			Soft	Domestic and stock
	St. Marys		1½				Drinking

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
JAMES CITY						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Croaker	3½ mi. E.	W. H. Davis	Coleman Whitaker	O	1897	0	200	3½	200	185	200
Diascond	2 mi. S.	——Brick Co.	H. E. Shimp	M	1908	.....	250?	....	....	....	....
Lee Hall	4 mi.S.W.	Duke & Smith	H. E. Shimp	O	1903	23	429	2	....	....	....
Lee Hall	4 mi.S.W.	Duke & Smith	H. E. Shimp & S. H. Fetterholf	O	1906	18	395	2	375	330	375
Lee Hall	near	H. M. Clement	S. H. Fetterholf	D	1906	40	....	....	....	300	....
Lee Hall	2 mi. W.	Charles Bailey	H. E. Shimp	M	1908	10	200	2	200	....	....
Jamestown	at .	Asso. Preservation of Va. Antiquities	SydnorPump&WellCo.	O	1905	12	270	6	270	....	270
Jamestown	1½mi.NE.	C. F. Ayers	Frank Carman	O	1906	15	300	3	295	171-271	298
Jamestown	1½ mi. N.	Chas. Babcock	Frank Carman	D	1906	12	320	3	310	15 45 190 260 280	298
Jamestown	⅛ mi. E.	Miss L. J. Barney	....	O	1894	10	290	3	....	....	....
Jamestown	1 mi. N.	G. L. Burleson	Frank Carman	O	1906	15	310	3	309	....	309
Jamestown	1½mi.NE.	E. Gilley	Frank Carman	O	1905	18	298	3	298	....	....
Jamestown	2 mi. E.	Miss Rose D. Johnson	....	..	1901	6	250?	7	....	....	....
Jamestown	....	Southern Land Co.	——McCormick	O	1906	20	270	1½	....	....	....
Lightfoot	1 mi.S.W.	Powhatan Hunting Club.	S. H. Fetterholf	D	1903	8	140	2	....	....	....
Williamsburg	¼m.N.W.	Eastern State Hospital	G. Valden	M	1888	80	876	3-1	....	....	....
Williamsburg	¼m.N.W.	Eastern State Hospital	Frank Gould	M	1902	84	280	8	....	....	....
Williamsburg	¼m.N.W.	Marshall Estate	Frank Gould	M	1899	84	285	6	....	....	....
Williamsburg	¼ mi. E.	Mrs. Israel Smith	G. Valden	M	......	88	299(?)	6	....	....	....
Williamsburg	½m.N.W.	William and Mary College	Frank Gould	M	1898	84	290	6	290	sever'l	290
Williamsburg	⅛mi.N.E.	G. Valden	Frank Gould	O	1888	70(?)	276	6	....	....	....
Williamsburg	¼ mi. W.	Williamsburg Knitting Mill	Frank Gould	M	1889	75	286	6	286	....	286
Norge	near	Chesapeake & Ohio Ry.	Sydnor Pump & Well Co.	O	1909	110	419	8	....	....	415
KING AND QUEEN											
Gressith	2 mi. W.	W. F. Anderson	W. Johnston	O	1885	11	206	2	206	150	180
King and Queen	near	County	Frank E. Pearce	M	1889	20	216	2	216	....	216
King and Queen	2mi.S.W.	S. Bird	Frank E. Pearce	M	......	18	200(?)	....	....	....	....
Little Plymouth	2mi.S.W.	R. H. Spencer	....	O	1886	20	168	1½	....	....	....
Mantapike	½ mi. S.	Mantapike Canning Co.	Jos. Ryland	D	1903	6	150	2	150	....	28
Plainview	5 mi. N.	Garrett Post	Wm. Johnson	O	1888	.....	210	2	210	215	....
Shackelford	3¼ mi.SW	W. H. Bland	J. V. Bray	O	1890	.....	175	2	175	160	175
Shackelford	3¼ mi.SW	R. M. Hart	Frank Pearce	O	1895	8	172	1½	172	160	172
Truhart	1½mi.SE.	Miss E. B. Savage	J. V. Bray	D	.....	.....	175	2	175	....	....
Walkerton	....	Dr. B. B. Bagby	W. H. Walker	O	1859	25	275	....	....	....	....
Walkerton	....	Ivan Clark	H. E. Shimp	O	1906	21	240	1½	225	....	225
Walkerton	....	P. P. Dillard	Frank Eaton	O	1889	32	265 250?	1½	....	....	20
Walkerton	....	H. B. Gray	Joseph Ryland	O	1889	85	355	1½	....	....	7
Walkerton	2 mi. N.	A. B. Gwathmey	H. E. Shimp	O	1906	8	190	1½	....	....	....

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
Gravel	Calvert	+20	20		60(?)	Alkaline	Domestic and medicinal
							Drinking
	Pamunkey	+30	10		63½		Domestic and stock
	Pamunkey	+30	2		65		Boiler
		+25				Soft	
	Calvert (?)	+41	40-29		65		Drinking, domestic and stock
Gravel	Calvert (?)	+30	78		64	Fine	Household and stock
Gravel	Calvert (?)	+40	¼		63(?)		Household and stock
	Calvert (?)	+20?	2½		63		Household and stock
	Calvert (?)	+41	70		64		Household and stock
	Calvert (?)	+40?	6				
	Calvert (?)		5				Household and stock
	Calvert (?)		¼		60		Stock
	Calvert (?)		2				Drinking
White quicksand		+38					No flow, abandoned
Sand	Calvert	+40		50	62(?)	Soft	Hospital purposes
	Calvert			100	62(?)		Hospital purposes
	Calvert					Hard, irony	Domestic
	Calvert	+34		60			Drinking, etc.
	Calvert	+27		150			Ice manufacturing
	Calvert	+38		1,000(?)			Boiler and washing
Coarse greensand	Pamunkey (?)	+40		200+		Soft, alkaline	For locomotives, not used
Rock	Calvert	+28	8			Alkaline	Domestic and stock
Black sand	Pamunkey	+18	1	15	60¾	Soft, slightly sulphur	Public, no longer flows
	Pamunkey	+16		10	61		No longer flows
Shells	Calvert			3		Good	Domestic and stock
	Calvert (?)	+20	7½		62	Soft	Canning factory
Under rock	Calvert (?)	+6	15			Soft, sulphur	Domestic
Shell rock	Calvert	+20	5		62½	Soft	Domestic and stock
	Calvert	+20	12		62	Soft	Domestic
	Calvert						
Sand under rock	Pamunkey	+30	$\frac{1}{10}$		58	Soft, sulphur	Domestic
Rock at 180	Pamunkey	+35	1⅔		62		Household and stock
Sand	Pamunkey		½		63		Household
	Potomac			2	60		Drinking and stock
Greensand with shells	Pamunkey	+35	20		63		Household

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
KING AND QUEEN—Cont.						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Walkerton	near	W. T. Haynes	Frank Eaton	O	1889	.....	260	1½	.....	.....	260
Walkerton	near	Hefron & Haynes Steamboat Co.	Frank Eaton	M	1888	5	185 330	1½	.....	.....	18
Walkerton	near	Mattapony Pickle Co.	J. V. Bray	O	1904	8	350	1½	.....	.....	330
Walkerton	near	Mattapony Pickle Co.	J. V. Bray	O	1902	6	260	1½	.....	.....	....
Walkerton	near	John A. Mitchell	John A. Mitchell	O	1891	32	372	1½	250	.....	....
Walkerton	near	Mrs. C. T. Roberts	Joseph Ryland	M	1895	32	250	1½	.....	.....	....
Walkerton	1 mi. E.	John N. Ryland	Joseph Ryland	O	1906	50	275	1½	275	.....	45 270
Walkerton	near	Miss Lucy Stacy	Joseph Ryland	M	1896	33	260?	1½	.....	.....	16
Walkerton	near	R. M. Trice	Frank Eaton	M	1889	.....	260?	1½	.....	.....	....
Walkerton	near	Mrs. Mary Turner	Frank Eaton	M	1880	32	260	1½	.....	.....	20
Walkerton	near	H. H. Walker	H. E. Shimp	O	1905	37	240	1½	.....	.....	....
Walkerton	near	Mrs. Melville Walker	.....	M	1889	35	270?	1½	.....	.....	45
Walkerton	near	Walkerton Pickle Co.	W. H. Walker	M	1904	.....	350	1½	.....	.....	....
KING GEORGE											
Dido	at	C. E. Davis, 2 wells	Chas. Pfeil	O	1898	8	175	1½	.....	150 90 15	....
Dogue	2 mi. E.	J. S. Dickinson	L. Rude	O	1897	40	260	2	.....	.....	....
Mathias Point	.....	W. Mayo	L. Rude	D	1907	12	175	....	.....	.....	....
Mathias Point	at	P. H. Pemberton	C. W. Walcott	O	1902	8	236	1¼	236	none	16 236
Pluck	near N.	Lyttleton Johnson	Chas. H. Jones	M	1895	6	190	2	190	none	....
Pluck	near	Johnson Bros.	.....	M	.....	8	300	2½	.....	.....	....
Pluck	¼ mi. N.	H. N. Stuart	.....	..	1893	8	50	1¼	42	.....	....
Port Conway	2 mi. N.E.	J. H. Law	.....	M	1905	28	305	....	.....	.....	....
Port Conway	1 mi. E.	R. V. Turner	Hammell & Hale	O	1905	20	250	1½	.....	.....	....
Port Conway	near	R. V. Turner	Hammell & Hale	O	1903	3	232	1½	224	15	219
Rollins Fork	2 mi. S.	Vulcan Fire Brick Co., (2 wells)	.....	M	1900	11	275?	1½	.....	.....	....
Sealston	2 mi. E.	John Curtis	Geo. Heflin	D	1904	30	250	2	.....	.....	....
KING WILLIAM											
Aylett	near	J. C. Fox	Jos. Ryland	D	1905	25	189	2	.....	none	20
Aylett	near	J. B. Moore	H. E. Shimp	O	1906	25	190	1½	180	.....	30 190
Cohoke	near N.	Cohoke Club	J. A. Smith	..	1886	18	215	2	215	.....	....
Cohoke	.....	Dr. Edwards	H. E. Shimp	D	1906	35	232	2-1	230	.....	230
Cohoke	1 mi. S. E.	J. W. Johnson	H. E. Shimp	D	1906	20	250	....	240	.....	20 240
Elsing Green	near W.	Roger Gregory	H. E. Shimp	D	1906	20	205	2	200	.....	190
Elsing Green	.....	Roger Gregory	H. E. Shimp	D	1906	20	300	2	.....	.....	230
King William	near	King William County	F. E. Pearce	..	1898	.....	350	....	.....	.....	....
King William	1½ mi. N.	John Cook	.....	M	1889	4	260	1½	.....	.....	....
Lester Manor	3 mi. W.	J. T. Dantey	H. E. Shimp	D	1906	20	245	3-2	240	.....	240
Lester Manor	3 mi. W.	Frank Robbins	H. E. Shimp	D	1906	40	400(?)	3-1	275	.....	70

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
Gravel	Calvert	+20	20		60(?)	Alkaline	Domestic and medicinal
							Drinking
	Pamunkey	+30	10		63½		Domestic and stock
	Pamunkey	+30	2		65		Boiler
		+25				Soft	
	Calvert (?)	+41	40-29		65		Drinking, domestic and stock
Gravel	Calvert (?)	+30	78		64	Fine	Household and stock
Gravel	Calvert (?)	+40	¼		63(?)		Household and stock
	Calvert (?)	+20?	2½		63		Household and stock
	Calvert (?)	+41	70		64		Household and stock
	Calvert (?)	+40?	6				
	Calvert (?)		5				Household and stock
	Calvert (?)		¼		60		Stock
	Calvert (?)		2				Drinking
White quicksand		+38					No flow, abandoned
Sand	Calvert	+40		50	62(?)	Soft	Hospital purposes
	Calvert			100	62(?)		Hospital purposes
	Calvert					Hard, irony	Domestic
	Calvert	+34		60			Drinking, etc.
	Calvert	+27		150			Ice manufacturing
	Calvert	+38		1,000(?)			Boiler and washing
Coarse greensand	Pamunkey (?)	+40		200+		Soft, alkaline	For locomotives, not used
Rock	Calvert	+28	8			Alkaline	Domestic and stock
Black sand	Pamunkey	+18	1	15	60¾	Soft, slightly sulphur	Public, no longer flows
	Pamunkey	+16		10	61		No longer flows
Shells	Calvert			3		Good	Domestic and stock
	Calvert (?)	+20	7½		62	Soft	Canning factory
Under rock	Calvert (?)	+6	15			Soft, sulphur	Domestic
Shell rock	Calvert	+20	5		62½	Soft	Domestic and stock
	Calvert	+20	12		62	Soft	Domestic
	Calvert						
Sand under rock	Pamunkey	+30	1/16		58	Soft, sulphur	Domestic
Rock at 180	Pamunkey	+35	1⅔		62		Household and stock
Sand	Pamunkey		½		63		Household
	Potomac			2	60		Drinking and stock
Greensand with shells	Pamunkey	+35	20		63		Household

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
KING AND QUEEN —Cont.						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Walkerton	near	W. T. Haynes	Frank Eaton	O	1889	.....	260	1½	.....	.....	200
Walkerton	near	Hefron & Haynes Steamboat Co.	Frank Eaton	M	1888	5	185 330	1½	.....	.....	18
Walkerton	near	Mattapony Pichle Co.	J. V. Bray	O	1904	8	350	1½	.....	.....	280
Walkerton	near	Mattapony Pichle Co.	J. V. Bray	O	1902	6	260	1½	.....	.....	....
Walkerton	near	John A. Mitchell	John A. Mitchell	O	1891	32	372	1½	250	.....	....
Walkerton	near	Mrs. C. T. Roberts	Joseph Ryland	M	1895	32	250	1½	.....	.....	....
Walkerton	1 mi. E.	John N. Ryland	Joseph Ryland	O	1906	50	275	1½	275	.....	45 270
Walkerton	near	Miss Lucy Stacy	Joseph Ryland	M	1896	33	260?	1½	.....	.....	16
Walkerton	near	R. M. Trice	Frank Eaton	M	1889	.....	260?	1½	.....	.....	....
Walkerton	near	Mrs. Mary Turner	Frank Eaton	M	1880	32	260	1½	.....	.....	20
Walkerton	near	H. H. Walker	H. E. Shimp	O	1905	37	240	1½	.....	.....	....
Walkerton	near	Mrs. Melville Walker	.....	M	1889	35	270?	1½	.....	.....	45
Walkerton	near	Walkerton Pickle Co.	W. H. Walker	M	1904	.....	350	1½	.....	.....	....
KING GEORGE											
Dido	at	C. E. Davis, 2 wells	Chas. Pfeil	O	1898	8	175	1½	.....	150 90 15	....
Dogue	2 mi. E.	J. S. Dickinson	L. Rude	O	1897	40	260	2	.....	.....	....
Mathias Point	.....	W. Mayo	L. Rude	D	1907	12	175	....	.....	.....	....
Mathias Point	at	P. H. Pemberton	C. W. Walcott	O	1902	8	236	1¼	236	none	16 236
Pluck	near N.	Lyttleton Johnson	Chas. H. Jones	M	1895	6	190	2	190	none	....
Pluck	near	Johnson Bros.	.....	M	.....	8	300	2½	.....	.....	....
Pluck	¼ mi. N.	H. N. Stuart	.....	..	1893	8	50	1¼	42	.....	.
Port Conway	2 mi. N.E.	J. H. Law	.....	M	1905	28	305	....	.....	.....	....
Port Conway	1 mi. E.	R. V. Turner	Hammell & Hale	O	1905	20	250	1½	.....	.....	....
Port Conway	near	R. V. Turner	Hammell & Hale	O	1903	3	232	1½	224	15	219
Rollins Fork	2 mi. S.	Vulcan Fire Brick Co., (2 wells)	.....	M	1900	11	275?	1½	.....	.....	....
Scalston	2 mi. E.	John Curtis	Geo. Heflin	D	1904	30	250	2	.....	.....	....
KING WILLIAM											
Aylett	near	J. C. Fox	Jos. Ryland	D	1905	25	189	2	.....	none	20
Aylett	near	J. B. Moore	H. E. Shimp	O	1906	25	190	1½	180	.....	30 190
Cohoke	near N.	Cohoke Club	J. A. Smith	..	1886	18	215	2	215	.....	....
Cohoke	.....	Dr. Edwards	H. E. Shimp	D	1906	35	222	2–1	230	.....	220
Cohoke	1 mi. S. E.	J. W. Johnson	H. E. Shimp	D	1906	20	250	....	240	.....	20 240
Elsing Green	near W.	Roger Gregory	H. E. Shimp	D	1906	20	205	2	200	.....	190
Elsing Green	.....	Roger Gregory	H. E. Shimp	D	1906	20	300	2	.....	.....	220
King William	near	King William County	F. E. Pearce	..	1898	.....	350	....	.....	.....	....
King William	1½ mi. N.	John Cook	.....	M	1889	4	260	1½	.....	.....	....
Lester Manor	3 mi. W.	J. T. Dantey	H. E. Shimp	D	1906	20	245	3–2	240	.....	240
Lester Manor	3 mi. W.	Frank Robbins	H. E. Shimp	D	1906	40	400(?)	3–1	275	.....	70

TABLE 5 *(Continued)*—***Data of wells in Coastal Plain Province of Virginia.***

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
terial	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
	Pamunkey						Household
	Pamunkey		1¼		61		Drinking
		+30?					
and	Potomac	+15	5		63½	Soft, alkaline, sulphur	Salting pickles
	Pamunkey	+30?	4		63		Salting pickles
	Potomac	+43?			64		Household
	Pamunkey	+25					
	Pamunkey	+33					
	Pamunkey	+33					Household
	Pamunkey		¼				Household
	Pamunkey	+32	⅛		60		Household
	Pamunkey	+35			60		Hotel
	Pamunkey	+35?					
	Potomac	+15				Soft, sulphur, alkaline	Pickle factory
	Pamunkey	+18	2½	6		Soft	Domestic, packing fish
	Potomac	+36				Hard	Domestic, stock
	Pamunkey						
	Potomac	+10	2				Stock, domestic and irrigation
	Pamunkey	+8 flows	several			Soft	Domestic, stock and oystermen
	Potomac	+3				Sulphur	Domestic, stock, too irony
	Pamunkey	+2		3		Very irony	Stock
	Pamunkey (?)	+29	2	3½	60		Household
	Pamunkey				61		House and stock
	Pamunkey	+23	13.5		61	Soft, slightly sulphur	Canning factory, domestic and stock
	Pamunkey		2		63		Drinking, boiler
tsand"	Potomac	+31	1½			Soft, sulphur	Domestic
sand	Pamunkey	+28	½		60½		Household and stock
green sand	Pamunkey		1¾		60½		Household and stock
sand rock"	Pamunkey	+31				Soft, iron	Domestic, stock
nsand	Pamunkey	+35?	$\frac{1}{16}$	1		Soft	Household and stock
sand	Pamunkey	+32				Soft	
sand	Pamunkey	+30	5			Soft	Drinking and stock
	Pamunkey	+30	7		62		Drinking and stock
							No flow, not used
	Pamunkey		3⅛		61		Household and stock, formerly boiler
y rock" nsand	Pamunkey	+31	4		60?	Soft	Domestic and stock
sand		+36	5		60?		Household and stock

TABLE 5 (*Continued*)—*Data of wells in Coastal Plain Province of Virginia.*

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
KING WILLIAM —Cont.						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Lester Manor....	3 mi. W.	J. A. Robins.............	H. E. Shimp.........	D	1907	20	200	3	200	....	190
Lester Manor....	....	T. L. Robins.............	....	..	......	30	200	3-2	250	19	240
Manquin	2 mi. S. W.	Miss Cora Skidmore....	Frank E. Pearce.....	M	1888	32	270	2½	270	none	270
Manquin	1 mi. S.	C. B. Chapman..........	Sydnor Pump & Well Co.	M	1896	30	237	6	....	....	237
Palls	1½ mi. SW	J. H. Montague..........	....	..	1888	32	399	1½	398	....	....
West Point......	....	City	Frank E. Pearce.....	M	......	8-15	165	1½	165	120	....
West Point......	....	City	Challenge Wind Mill & Feed Co. (2 wells)..	M	1904	10	335	3	337	120 165	....
West Point......	½ mi. N.	Mrs. S. E. Carr........	....	M	1886	8	165	1½	....	....	....
West Point......	1 mi. N.	Denmead Bros.	J. V. Bray...........	O	1892	5	105	1½	105	....	165
West Point......	1 mi. N.	Denmead Bros.	Frank E. Pearce.....	O	1895	2	158	1½	158	105	20 155
West Point......	¼ mi. E.	B. W. Edwards..........	Frank E. Pearce.....	M	1888	2	158	1½	....	....	....
West Point......	¼ mi. N. E.	Dr. W. T. Gatewood....	J. Frank Smith......	O	1886	14	180	2	....	....	....
West Point......	1 mi. N. E.	Dr. W. T. Gatewood....	J. Frank Smith......	O	1902	14	315	1½	....	....	....
West Point......	1 mi. N. W.	Guthrie & Kidd..........	J. V. Bray...........	M	1906	1-3	169	1½	160	....	....
West Point......	....	B. W. Hefron...........	....	O	......	7	165	....	....	....	....
West Point......	....	B. W. Hefron...........	....	O	1903	7	325	....	....	....	....
West Point......	....	B. W. Hefron...........	....	..	......	7	120	1½	....	....	....
West Point......	1 mi. S. E.	J. W. Marshall..........	J. Frank Smith......	M	1904	5	165	1½	....	....	....
West Point......	¼ mi. E.	J. W. Marshall..........	J. Frank Smith......	O	1902	14	332	2	....	....	....
West Point......	¼ mi. S.	T. O'Conner	....	..	....	8	165	1½	....	....	160
West Point......	near S.	J. W. Owens.............	J. V. Bray...........	O	1899	20	165	1½	160	15	165
West Point......	⅞ mi. S. E.	M. M. Puller............	J. Frank Smith......	O	1902	8	325	....	....	....	....
West Point......	1 mi. S.	Geo. W. Richardson....	....	O	......	6	160	1½	160	120	....
West Point......	1 mi. S.	Geo. W. Richardson....	H. E. Shimp.........	O	1905	6	366?	4- 1¼	366?	120	300?
West Point......	¾ mi. S. E.	Geo. W. Richardson....	Sydnor Pump & Well Co.	O	1904	10	325	1½	....	....	....
West Point......	½ mi. N.	J. W. Sheldon	J. V. Bray...........	O	1901	15	175	1½	....	....	....
West Point......	¾ mi. S.	[a]Southern R. R. Co. (big well)	....	M	1881	5	120?	6	120	....	....
West Point......	¾ mi. S.	Southern R. R. Co...... (6 wells)	Frank E. Pearce.....	M	1888	5	160	2	160	....	30 160
West Point......	1 mi. S. E.	Southern R. R. Co......	E. Wilkinson	D	1900	5	165	1½	165	120	...
West Point......	1 mi. S. E.	Southern R. R. Co.	E. Wilkinson	D	1899	5	165	1½	165	120	....
West Point......	2 mi. S. E.	United States	E. Wilkinson	D	1893	.....	165	2	....	....	160
West Point......	½ mi. S W	West Point Ice Co. (2 wells)	Frank E. Pearce.....	M	1888	6	185	2	185?	....	185?
West Point......	¼ mi. S.	Wm. Wheeler	J. Frank Smith......	D	1902	8	326	1½	315	112 150	306
West Point......	¼ mi. S. E.	E. Wilkinson	J. V. Bray...........	O	1887	10	165	1½	120	....	....

[a] Southern R. R. had about 15 wells.
[b] Initial head 29 feet.
[c] Flow at first 20 gallons per minute.
[d] Combined yield of wells.

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
Greensand	Pamunkey		5½			Soft	
	Pamunkey		1½			Soft	
Sand	Potomac (?)	+39	2		61		Household and stock
Gray micaceous sand	Potomac (?)	+39	6½				Household, boiler supply, stock
	Potomac (?)	33	⅔		61		Household and stock
	Calvert	+8		2-6		Soft	Public
Sand	Pamunkey	+20	37		66	Soft	City water works
	Calvert		2				Domestic
	Calvert	+9?	½		62	Soft sulphur	Boiler
	Calvert	+10	20?		63	Soft	Drinking
	Calvert						Boiler
	Calvert	+11		12	62		Household
	Pamunkey				67½		Household
	Calvert	+13					Boiler at brick yard
	Calvert					Soft	Household
	Pamunkey					Soft	Household
	Calvert				65	Soft sulphur	Drinking
	Calvert	+14	10?		63		Washing oysters
	Pamunkey	+20			64½		Household
	Calvert		¾-2⅛		62		Stable
Sand	Calvert	[b]+18			61¾		Drinking
	Pamunkey		9½		67		Household
	Calvert		7		63	Soft	Washing oysters
Black sand	Pamunkey	+30?	70(?)		66	Soft	Washing oysters
	Pamunkey				65		Household
	Calvert		5		61¾		Household
	Calvert					Soft, sulphur	Drilled for locomotive, little used
	Calvert		4½			Soft	Drinking or steamboats and wharf
Gravel	Calvert				63½	Soft	Drinking at Beach Park
	Calvert		[c]7½		65?	Soft	Park at Terminal Hotel, drinking, etc.
	Calvert	+20	50?			Soft	Drilled for dredge, used now occasionally by boats
	Calvert		[d]21	42	61¼	Soft	Ice mfg., drinking
Sand and gravel	Pamunkey	+18	20			Soft	Domestic and stock
Sand	Calvert	+ 7		8	62		

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
						Ft.	Ft.	In.	Ft.	Ft.	Ft.
LANCASTER											
Bertrand	near S.	T. J. Ratcliffe & Co.	T. J. Ratcliffe	O	1889	9	272	1¼	268	220	90
Bertrand	.....	J. C. Ewell (2 wells)	L. T. Custer	O	1902	12	275	2	.....	.....	80
Irvington	1 mi. N.W.	Carter Creek Fish Guano Co.	R. H. Milligan	O	1899	6	580	3–2	580	550 450 350	580
Irvington	1 mi. N.W.	Carter Creek Fish Guano Co.	.....	..	.....	.....	330	1½	330	.....	.....
Irvington	¾ mi. SW	Est. of I. H. Francis	R. H. Milligan	D	1905	5	537	3	.....	.....	.....
Irvington	¾ mi. SW	Est. of I. H. Francis	.....	..	.....	6	330?	1½	.....	.....	.....
Irvington	near	W. A. Dameron & Bros.	L. Rude	O	1891	3½	330	1½	330	.....	.....
Irvington	near	Messick & Gunby	H. A. Crittenden	O	1903	4½	450?	1½	.....	.....	.....
Kilmarnock	near	.....	R. H. Milligan	D	1903	.....	637	2	.....	.....	.....
Lancaster	.....	Wm. Chilton	.....	..	.....	.....	250	1½	.....	.....	100
Lancaster	near	County	L. Rude	M	.....	77	450	.....	.....	.....	.....
Merry Point	near	Crallé, Jones & Co.	J. C. Ewell	M	1902	.....	325	2¼	325	.....	100
Millenbeck	near S. E.	Millenbeck Oyster Co.	L. F. Carter	M	1892	10	315	1½	.....	.....	none
.....	.....	W. Warren	H. E. Shimp	D	1904	.....	325	1	.....	.....	.....
Monaskon	.....	B. L. Farinholt	.....	O	1889	6	300	1½	.....	.....	.....
Monaskon	.....	B. L. Farinholt	.....	..	.....	6	255	.....	.....	.....	.....
Ocran	.....	J. F. Bellows	.....	..	.....	6	507	3	.....	.....	.....
Ocran	.....	Bellows & Squires	R. H. Milligan	O	1907	10	660	3	660	.....	660
Weems	.....	B. G. Doggett and Chas. Chance	L. Rude	M	1896	3½	330	1½	330	.....	.....
Weems	.....	B. G. Doggett and Chas. Chance	L. Rude	..	1894	.....	260	1½	.....	.....	.....
Weems	.....	W. Messick	H. E. Shimp	D	1904	.....	485	2–1	.....	.....	.....
Westland	.....	B. L. Farinholt	.....	M	1896	.....	443	.....	.....	.....	.....
Whealton	1½ mi. W.	O. D. Hale	Hammell & Hale	..	1904	10	244	1½	233	.....	.....
Whealton	near	Lewis, Lankford-Tull Co.	Hammell & Hale	D	1902	8	256	1½	251	none	214
Whealton	near	J. W. Whealton	.....	..	1894	6	262	1½	.....	.....	.....
Whealton	.....	Whealton Packing Co. (3 wells)	Hammell & Hale	..	1894–1903	4	265	1½	.....	70	.....
Whitestone	near	.....	.....	..	1890	.....	300+	.....	.....	.....	.....
MATHEWS											
Fitchetts	.....	Fitchetts	J. W. T. Robertson	..	1904	.....	100±	2	.....	.....	.....
Mathews	near	County	H. E. Shimp	M	1905	2	817	2–1	.....	125	.....
Mathews	near	.....	Hammell & Hale	M	.....	8	390	.....	.....	.....	.....
Mathews	3 mi. S.	R. T. Sears	Wm. S. Johnson	M	1891	8	300±	.....	.....	.....	.....
Mathews	near	.....	G. F. Steer	M	1891	8	360±	.....	.....	.....	.....
Port Haywood	1½ mi. E.	Sterling Diggs	H. E. Shimp	O	1904	10	112±	3–2	.....	.....	.....
Port Haywood	1½ mi. N.	Perry Lumber Co.	H. E. Shimp	D	1907	10	107	3–2	100	.....	100
Traders	1 mi. N.	John M. Campbell	.....	D	1907	15	110	3–2	100	.....	.....

[a] Flow at first 15 gallons per minute.

TABLE 5 (*Continued*)—*Data of wells in Coastal Plain Province of Virginia.*

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
Sand	Calvert	+18	1½			Sulphur	Domestic, stock, washing oysters
Clay	Calvert	+18	2			Soft	Domestic, stock, washing oysters
Sand	Pamunkey (?)	+35	30		69	Soft	Boiler, domestic and stock
	Calvert					Soft sulphur	Not used
	Pamunkey (?)		[a]33⅓		69		Drilled for hotel supply, household
	Calvert		1¼		65	Soft, sulphur	Household
	Calvert	+4	½		64	Soft, sulphur	Drinking
		+6?	2		64	Soft	Drinking, washing oysters, canning
	UpperCretaceous		140				
	Calvert						
	Calvert	+15 +32					No flow, abandoned
	Calvert	+4?	½			Sulphur	Domestic, stock, boiler
	Calvert	±0				Sulphur	Drinking, cooking
	Calvert						
	Calvert	+12	50-12			Soft, sulphur	Domestic and boats
	Calvert						
	Pamunkey (?)		7				
Sand	UpperCretaceous						Fish factory
	Calvert	+6	2⅛		64	Soft, sulphur	Drinking
	Calvert						
	Calvert						
							No flow, abandoned
Porous sand rock	Calvert	+18	15			Soft	Domestic and stock
Shell rock	Calvert		16		61(?)	Soft	Canning factory, domestic and stock
	Calvert						Domestic and stock
	Calvert	+15	20			Soft, sulphur	Canning factory, domestic and stock
							No flow, abandoned
	St. Marys (?)						Canning factory
		+6½	1		59	Soft, sulphur	Drinking
							Never used, no flow
							Never used, no flow
							Never used, no flow
Fine sand	St. Marys (?)	+5		very small		Sulphur	Abandoned
	St. Marys	+7		30	58	Soft	Boiler, drinking and stock
	St. Marys				57½		Domestic and stock

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
						Ft.	Ft.	In.	Ft.	Ft.	Ft.
MIDDLESEX											
Bushy							300+				
Butylo	1½mi.SE	B. L. Farinholt		M	1895	0	280	1½			
Bayport	¼mi.S.E.	Bland Bros.	Hammell & Hale	D	1902	7	248	1½	242	none	218
Bayport	near	R. H. Bland & Co., 3 wells	Hammell & Hale	O	1894–1906	6	260–300	1½			
Bayport	near	B. L. Farinholt	L. Rude	M	1891	6	300	1½			
Dew	near	L. Nelson	L. Rude	O	1894	4	297	1½			50
Sandy Bottom	1 mi. E.	D. A. Taylor	J. W. T. Robertson	O	1901	7	78	2	75	35	74
Urbanna		G. S. Chowning	H. E. Shimp	O	1900	5	250	1½			
Urbanna		G. W. Hurley	R. H. Milligan	D	1904		478	3			300
Urbanna		G. W. Harley, (2 wells)	H. E. Shimp	D	1901	4	275–290	1½			
Urbanna		G. W. Harley, (2 wells)	L. Rude			2	227	1	227		70
Urbanna	¼ mi. E.	Hoskiss & Donaldson	G. P. Beazeley	O	1896	6	272	2	272		
Urbanna		Urbanna Mfg. Co		M	1902	2	275?	1½			
Urbanna		G. V. Wagemen	G. V. Wagemen		1905	6	232	1½			
NANSEMOND											
Chuckatuck	1 mi. E.	Dr. Livins Langford	Tom Johnson	O	1906		188	2			
Chuckatuck				M	1908	25	300		300		
Everets	1½ mi. E.	Josiah Gray	E. E. Wagner	D	1904	36	100	1¼	50		
Everets		G. A. Greene	E. E. Wagner	D	1904		90	1¼			
Everets		H. Saunders	E. E. Wagner	D	1904	5	50	1¼			
Everets		T. J. Saunders	C. M. Johnson	O	1896	5	54	1¼	50		
Everets		E. E. Wagner	E. E. Wagner	D	1900	8	100	1¼	100	50, 80	80
Reids Ferry		Nansemond River Brick & Tile Co.		O	1902	15	150	2			
Suffolk	1 mi. E.	A. B. Cramer	A. B. Cramer		1905	55	253				
Suffolk	½mi.N.E.	Gay M'f'g Co.	Sydnor Pump & Well Co.		1896	55	300				
Suffolk			Leach		1885		250				
Suffolk		Norfolk & Portsmouth Traction Co.	Sydnor Pump & Well Co.		1901	58	803?	6	650?		
Urbanna		L. B. Wageman		M		5	250	1½			
Urbanna	near		R. H. Milligan	D	1906	10	590	3		300	300
Waterview		Powell & Son	Geo. Heflin		1906		350	2			
NEW KENT											
Boulevard		Wm. Weber	Sydnor Pump & Well Co.	O	1902	22	260	4½	265	224	[illegible]
Lanexa		Robert Turner	H. E. Shimp	M	1908	28(?)	110	2	110		
Lily Point		Richmond Shooting and Hunting Club	H. E. Shimp	D			225	1½			220
Plum Point	near	Frederick Knoll	J. V. Bray	O	1897	9	150	1½	150		35
Plum Point	⅛mi.S.E.	J. L. Richardson	Frank E. Pearce	O	1891	12	168	1½	168	120	165
Providence Forge	⅛ mi. E.	R. E. Richardson	P. H. Sweet	M	1896	25(?)	215	1			160?

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[a] Initial flow 25 gallons per minute.
[b] Flowed at first.

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
	Chesapeake					Soft	Not used
	Calvert	+16	20			Sulphur	General
Shell rock	Calvert		16			Soft	Domestic, stock, canning factory, packing
	Calvert	+20				Hard (?)	Drinking and cooking
	Calvert	+18	20		64		Washing oysters, drinking
Rock	Calvert		½			Soft, alkaline	Drinking
Gravel	Columbia(?)	+2				Hard, irony	Domestic except laundry
	Calvert		3				Drinking, etc., at boat yard
	Pamunkey	+25?	75		68		Making ice
	Calvert				66½		Making ice
	Calvert	+15	3	105			Making ice
Under rock	Calvert	+12	[a]3			Soft, sulphur	Boiler, pickling cucumbers
	Calvert					Soft, sulphur	Household
	Calvert	+10	5		65½		
	St. Marys						No flow, abandoned
		+30				Soft	
	St. Marys	+17					Household
	St. Marys						Household
	St. Marys						Household
Sand	St. Marys	+9	⅓		58		Household and stock
White sand	St. Marys	+15	2½			Soft	Household
							No flow, abandoned
							No flow, abandoned
							No flow, abandoned
							No flow, abandoned
Sand	UpperCretaceous	+32		11			Ice making
	Calvert				63		Canning factory
	UpperCretaceous	+34		105	67		Not completed
	Calvert						
Soft	Pamunkey	+32					
Sand	Pamunkey						
White sand with black	Pamunkey	+40?	3				
Shell rock	Chesapeake				58?	Lime?	Domestic and stock
Sand	Chesapeake	+12				Soft	Domestic and stock
	Pamunkey	+15[b]			60½		Store, household

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
NEW KENT—Cont.						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Providence Forge	⅛ mi. NW	E. B. Townsend	Sydnor Pump & Well Co.	M	1902	20	216	4½	216	....	215
Providence Forge	....	James Christian	H. E. Shimp	M	1908	25(?)	215	2	215	....	....
Providence Forge	....	Southern Pine Lumber Co.	....	M	1907	25	220	2	.....	....	....
Whitehouse	near S. E.	Southern Railway	P. H. Sweet	D	1893	5(?)	200	1½	200	....	....
Walkers	near	——McCann	H. E. Shimp	M	1909	25	200	2	200	....	....
NORFOLK											
Buell	....	E. H. Barney Co.	....	..	......	.....	.....	.....	.....	....	....
Buell	1 ½mi. N.	Pocomoke Guano Co.	Walter Goodman	O	1906	6	86	2½	86	12	82
Buell	N.	Roanoke R. R. & Lumber Co.	....	..	......	.....	53 562	1½ 5	53	....	....
Buell	....	Norfolk Crosoline Co.	....	..	......	.....	50–75	2	60	....	....
Greatbridge	⅛ mi. N.	J. E. Hall	J. E. Hall	O	1902	5	75	3	70	....	....
Buell	....	....	....	..	......	.....	562	.....	.....	....	....
Lambert Point	....	Norfolk & Western R. R.	A. L. Miller	O	......	13	616	12–3 6	110	603	....
Pinners Point	....	Va.-Carolina Chem. Co.	J. H. K. Shannahan	..	1903	.....	40	4	40	....	....
Piney Beach	¾mi.N.E.	Jamestown Exposition Co.	Norfolk Mfg. & Supply Co.	O	1906	10	50	2½	10	none	....
Norfolk	....	City	....	M	......	10	140	6	.....	....	....
Portsmouth	....	Portsmouth Retail Lumber Corporation	....	..	1907	13	48	1½	.....	....	....
Rixton	....	Geo. S. Bunting	Geo. S. Bunting	O	1890	10	575	2–1	.....	....	200
NORTHAMPTON											
Cape Charles	1¼mi.SE	New York, Phila. & Norfolk R. R. (24 wells)	T. M. Ward	O	1900	8	40, 90	3	.....	8	10, 20, 30, 40, 90
Cape Charles	....	Wharton Fisheries Co.	R. H. Milligan	D	1899	3	249	3	.....	....	....
Cape Charles	....	Scott Estate Town and 17 wells	Eclipse Windmill Co.	M	1886	12	400	.....	.....	....	....
Cape Charles	....	Heckle & Kellogg	....	M	......	10	16–40	.....	.....	....	....
Capeville	3 mi. E.	J. H. Roberts	J. W. T. Robertson	O	1902	1	189	1½	125	....	....
Cheriton	....	Huff Bros.	Huff Bros.	O	......	.....	63	2	16	....	....
Mockham Island	....	....	J. W. T. Robertson	..	......	.....	189	.....	.....	....	....
Nassawadox	....	W. A. Jones (2 wells)	....	O	1906	3	75	1½	.....	....	....
Nassawadox	2½ mi. NE	Thomas Upshur	W. M. E. Tilghman	D	1904	5	127	1¼	.....	....	....
Oyster	near	W. T. Travis	J. W. T. Robertson	D	1901	3	185	1½	171	....	....
Oyster	....	W. T. Travis	J. W. T. Robertson	D	1901	3	205	1½	175	....	....
Oyster	....	W. T. Travis (3 wells)	J. W. T. Robertson	M	1901	.....	175–200	1½	.....	....	....
Bone Island	8 mi. E.	Ashton Starke	....	O	1906	6	169	1½	169	....	....
Willis Wharf	....	W. Ballard	J. T. Walkley	D	1905	15	98	1½	98	46 18	....

[a] Initial flow 65 gallons.

TABLE 5 (*Continued*)—*Data of wells in Coastal Plain Province of Virginia.*

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
Sand	Pamunkey	+27?			61		Domestic
Sand	Pamunkey	+20					Domestic
Sand	Pamunkey	+25					Drinking and boiler
Blue sand	Pamunkey	+13	1⅔			Soft	Domestic
Sand	Pamunkey	+15					Domestic
Gravel, sand and shell	Columbia	±0				Hard	Boiler and domestic
Sand	Columbia (?)						Drinking
		+10				Irony	Not used
Gravel		+1½?			70		Domestic and stock
	Columbia (?)	+8				Hard	Domestic, stock and boiler
	Calvert (?)	+5				Alkaline, saline	
Fine micaceous sand		+28	[a]51		72	Saline	Drinking, washing
Gravel	Columbia		30			Salty	
Sand and gravel	Columbia	±0				Alkaline	Drinking, boiler
	Yorktown (?)	+4				Irony	Abandoned
Gravel	Columbia						
							No flow, abandoned
Sand	Columbia	+0		100			Locomotives, machine shops
Gravel and sand	St. Marys (?)	+1	10	80		Brackish	Boiler
							No flow, abandoned
							Town supply, making ice
Shells	Chesapeake (?)	—½				Good	Domestic and stock
	Columbia						Domestic
		±0					
	Columbia	+4					Domestic and stock
	Columbia (?)	+6	1½				Domestic and stock
	Chesapeake		2			Soft, slightly sulphur-bearing	Domestic
	Chesapeake		2				Domestic
	Chesapeake						Boats, domestic and drinking
Sand	Chesapeake	-6	¾			Soft, slightly sulphuretted	Drinking, etc.
Shells	Columbia					Hard	Domestic

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
NORTHUMBERLAND						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Bond Point	near	A. M. Byers	Chas. H. Jones	M	1903	5	200(?)	....	....	....	....
Bond Point	....	....	L. Rude	..	......	.....	265	1½	265	....	....
Coan	near	T. H. Fallin	L. Rude	O	1888	53?	265	1½	260	....	....
Coan	near	T. H Fallin (2 wells)	Chas. H. Jones	O	1896	1½	270	1½	260	240	....
Coan	....	T. H. Fallin	T. H. Fallin	O	1898	0	310	1½	300	240	90
Coan	3 mi. N.	T. H. Fallin	....	O	......	3	290	....	.....	....	....
Coan	....	T. H. Fallin	....	O	......	4	318	....	.....	....	....
Cowart	near S. E.	S. Cowart	Hammell & Hale	O	1908	5	310	1½	310	280	150 310
Cowart	....	J. L. Dobyns	....	M	......	.....	288	2	.....	....	....
Cowart	....	L. Hedley	....	..	......	.....	......	....	.....	....	....
Fairport	near S. E.	McGill & McNeal Co.	R. H. Milligan	O	1903	3	690	2	690	....	....
Fairport	....	....	J. H. K. Shannahan	M	1898	6	662	...	650	....	..
Fairport	....	Morris-Fisher Co.	....	..	......	.....	398	1½	.....	....	....
Fleeton	⅛ mi. SW	Fleets Point Devel. Co.	R. H. Milligan	O	1904	8	746	2	746	240 400 692 710 721	....
Fleeton	....	Fleets Point Devel. Co.	R. H. Milligan	D	......	.....	690	2	.....	....	....
Heathsville	1 mi. N.	W. C. Snow	S. E. Booth	O	1896	6	265	2	265	none	....
Hyacinth	2 mi. S.W.	Roland Park	Chas. H. Jones	..	1904	5	270(?)	1½	.....	....	....
Hopeside	....	S. A. Whittaker	S. A. Whittaker	..	1904	8	365	4	365	....	20
Lewisetta	....	Gavner Bros.	....	M	......	.....	325–700	....	.....	....	....
Lewisetta	....	C. R. Lewis & Co.	J. H. K. Shannahan	..	1894	.....	317	5–2	.....	....	....
Lodge	½ mi. S.	Benj. Chambers (3 wells)	L. Rude	..	......	.....	255	1½	240	none	100
Mila	near	Hinton-Toulson Oil & Guano Co.	R. H. Milligan	O	1904	10	635	3	635	none	600
Mundy Point	....	....	....	M	......	.....	270(?)	2	.....	....	....
Mundy Point	near E.	W. J. Courtney	N. M. Shannahan	O	1899	6	268	6	.....	....	....
Reedville	near S.W.	Edwards & Reed Co.	R. H. Milligan	O	1902	5	685	2	682	350	....
Reedville	....	Haynie & Snow Co.	R. H. Milligan	D	......	.....	683	2	.....	....	....
Reedville	....	Jas. C. Fisher	R. H. Milligan	M	1904	.....	698	2	698	400	....
Reedville	....	McGill-McNeal Co.	R. H. Milligan	D	1908	3	680	3	680	....	....
Reedville	near	McNeal-Edwards Co.	R. H. Milligan	O	1902	5	682	2	682	....	....
Reedville	near	Albert Morris	R. H. Milligan	D	1904	8	724	2	690	none	600
Reedville	....	Morris & Fisher Co.	....	..	......	.....	405	....	.....	....	....
PRINCESS ANNE											
Virginia Beach	....	Princess Anne Hotel	....	..	1890	8	73	2	.....	....	....
Virginia Beach	....	Princess Anne Hotel	....	..	1889	8	600	....	.....	....	....
Waterway	....	Norfolk City Water Wks.	C. L. Parker	..	1898	11	1,750	12–4½	1,480	783, 1,227, 1,750	....

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
	Calvert		1½				
	Calvert	flows					
	Calvert	+12	¾		63		Drinking
	Calvert	+10	1½				Canning factory and domestic
	Calvert		7½				Canning factory and domestic
	Calvert		1				Domestic
	Calvert		1				Domestic
Rock	Calvert	+8	3			Soft, slightly sulphur	Drinking
	Calvert	+6	2				Domestic
Sand	UpperCretaceous	+35	45			Soft	Boiler at fish factory
Sand	UpperCretaceous	+30	75				
	Calvert (?)		2			Soft	
Sand	UpperCretaceous	+35	40			Soft, alkaline	Boats, domestic and stock
	UpperCretaceous		10			Soft, alkaline	Boats, domestic and stock
Sand	Calvert (?)		3			Soft, sulphur	Drinking
	Calvert		1¼		62½		Not used
Gravel and sand	Calvert						
Gravel			3–18				
	Calvert		17				
Porous rock	Calvert	+14			62	Slight sulphur	Boilers, domestic
Rock at 500 Black sand	UpperCretaceous	+40	45			Soft, alkaline	Fish factory boiler
	Calvert		1, ⅓			Soft	Household and stock
	Calvert	+12				Soft, alkaline	Washing oysters
Sand	UpperCretaceous		33	30		Soft	Fish factory, boiler and drinking
	UpperCretaceous		45				
	UpperCretaceous		18				
Sand	UpperCretaceous	+38	50			Soft	Fish factory boiler
Sand and gravel	UpperCretaceous	+25	35			Soft, alkaline	Fish factory boiler and drinking
Sand	UpperCretaceous	+38	40	200		Soft	Washing, drinking
	UpperCretaceous						
	Columbia					Irony	Washing, etc., no longer used
							No flow, abandoned
Sand	Upper Cret's (?)	+25?	75		76	Saline, sulphur	Part of public supply

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
						Ft.	Ft.	In.	Ft.	Ft.	Ft.
PRINCESS ANNE—Cont.											
Waterway	....	City of Norfolk..........	....	..	1894	.....	730	6-3	730	12, 300	....
PRINCE GEORGE											
Blairs	2 mi. W.	David Dunlap	A. L. Davis..........	M	1908	65	307	4	.....	60	....
City Point......	⅛mi.NW	Misses Epps	Sydnor Pump & Well Co.	O	1905	55	111	6	108	85	108
City Point......	⅛mi.NW	Misses Epps	....	O	......	55	53	8	.....	....	....
PRINCE WILLIAM											
Agnewville	near E.	Rufus Davis	Henry Daniels.........	..	......	.....	65	6	45	....	....
Myron	....	Washington Fertilizer Co.	W. O. Miller	D	1901	.....	257	4	238	127 167	[illegible]
RICHMOND											
Downings	....	W. B. Hale	Hammell & Hale.....	..	1901	8	241	1½	232	....	[illegible]
Ivondale	near E.	Mrs. J. H. Lemoine......	....	O	1889	50	254	2½	.....	....	....
Naylors	....	A. A. Taliaferro	H. E. Shimp.........	D	1904	.....	320	1	.....	....	....
Naylors	near S.	Waddington & Holme...	L. Rude	O	1894	.....	320	1½	225	160 250	....
Naylors	near S.	Waddington & Holme...	L. Rude	O	1893	5	386	1½	386	160 280 290	[illegible]
Sharps	¾ mi. NW	P. Y. Barber	L. Rude	O	1899	15	240	1½	240	....	....
Sharps	....	A. J. Davis............	....	..	......	.....	325	.....	.....	200	....
Sharps	....	F. Downing	....	..	......	.....	325	.....	.....	200	....
Sharps	1 mi. N.E.	J. M. McCarty..........	L. Rude	O	1894	10	240	2	240	....	....
Sharps	¼ mi. NW	D. W. C. Sharp (2 wells)	L. Rude	O	1890	4	212	1½	212	90	....
Sharps	....	E. Sharp	L. Rude	O	......	3	230	1½	.....	....	[illegible]
Sharps	¼ mi. NW	G. L. Smith & Bro. (2 wells)	L. Rude	O	1903	+3	245	2	245	....	....
Sharps	¼ mi. NW	J. B. Smith	L. Rude	..	1888	15	255	1½	250	....	....
Sharps	¼ mi. NW	....	L. Rude	D	1907	4	440	1½	230 365	....	....
Warsaw	3 mi. E.	E. W. Garland........ ..	L. Rude	O	1899	11½	188	2	187	65	[illegible]
Warsaw	....	E. W. Garland..........	E. W. Garland.......	..	1893	10	68	36	68	....	....
Warsaw	3mi. S.	W. A. Jones (2 wells)....	W. S. Johnson.......	M	1890	22	200	1½	200	....	....
Warsaw	3mi. S.	M. D. Kalbach..........	——Hale	O	1906	8	181	1½	177	....	176
Warsaw	3mi. S.	G. M. Sydnor (2 wells)...	——Hale	..	1906	3	180	1½	177	....	[illegible]- 177
Warsaw	2 mi. E.	Totuskey Canning Co.....	H. E. Shimp.........	M	1899	5	177	1½	.....	....	[illegible]
Warsaw	....	Frank Garland	Hammell & Hale......	..	1902	.....	165	.....	.....	....	....
Wellfords	2 mi. S.E.	W. G. Brockenbrough....	L. Rude	O	1904	.....	366	¾	366	180	[illegible]
Wellfords	....	H. T. Douglas, Jr.......	Hammell & Hale....	O	1894	20	227	2	227	60, 190	....
Wellfords	near N.	Frank Garland	Hammell & Hale....	O	1902	4	161	1½	165	....	114
SOUTHAMPTON											
Arringdale	near	Camp Manufacturing Co. (4 wells)	J. T. Moore and others	D	1891	30	75	1½	75	....	[illegible]
Boykins	....	W. D. Barden............	....	M	......	.....	90	2	.....	....	....

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
			85				Not used
		+30					No flow, not used
Sand	Patuxent	+15		25			Household
	Pamunkey						Abandoned
Gravel						Hard	Domestic
Coarse sand and gravel	Patuxent	55		320		Soft	Boiler, domestic
Rock at 200 **gravel sand rock**	Calvert	+18	18			Soft	Domestic
Sand	Calvert	+6				Hard, iron and sulphur	Household
	Pamunkey						
Black sand	Pamunkey	+30	2				Domestic and canning factory
	Pamunkey	+25	3		63		Domestic and stock
Sand	Calvert	+12				Soft	Household and stock
	Pamunkey	+20					
	Pamunkey	+20					
Gravel	Calvert	+26	530		63	Soft	General
Sand	Calvert	+16				Soft	Washing oysters
Rock	Calvert	+9				Soft	Canning factory
Gravel	Calvert		4			Soft	Washing oysters, drinking
Gravel	Calvert	+14				Soft	Household
Fine gray sand	Pamunkey (?)					Soft	
Sand	Calvert	+36	16		62½	Soft, sulphur	Drinking
	Calvert	+30	16				
	Calvert		¼		60		Domestic
Sand	Calvert	+20	2		61		Boiler at saw mill
Black sand	Calvert	+20	12		62		Drinking and canning factory
	Calvert	+20	5		62		Canning factory
Rocky clay	Calvert						
Clay	Pamunkey	+20	5		62?	Soft, sulphur	Household and stock
Rock	Calvert	+40	3½			Sulphur, iron	Household
Shell rock	Calvert	+22	24			Soft	Tomato canning factory, drinking
	St. Marys	+40?	6			Hard	Domestic and stock
	St. Marys		+10			Slightly alkaline	

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
SOUTHAMPTON—Cont.						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Boykins		J. W. Drury		M			105	2			
Boykins		E. H. Grizzard		M			87	1½			
Boykins		M. J. Knight					98	2			
Boykins		R. M. Knight		M			110	2			
Boykins		Henry de Laathe		M			90	2			
Boykins		F. M. Powell	P. P. Ellis	M			100	2			
Boykins	near	W. A. Powell	P. P. Ellis	O	1908		85	2	85	none	85
Boykins		Town of Boykins		M			85	2			
Boykins		W. W. White	J. T. Moore	M			130	2			
Branchville	near	P. G. Ellis	R. G. Ellis	O	1901		250	2	250	15-150	
Branchville	near	P. P. Ellis	P. P. Ellis	O					235		
Branchville	2 mi. S.E.	B. H. Beale	P. P. Ellis	D		15(?)	130	1	130		
Branchville	near	Grizzard Bros. & Co.	P. P. Ellis	M					150		
Branchville	near	T. J. Harrell	George Wilkins	M		85	207	2	90 140 160		
Branchville	near	T. E. Peat	P. P. Ellis	D		20	130	1½	130		
Capron		Trent & Vinson		O		50(?)	400	2			
Capron		Trent & Vinson		O		50(?)	225	2			
Courtland		R. F. Whitfield	J. T. Moore	D	1910	28	165	2			
Courtland		Bain & Co.	J. T. Moore	M			140	2			
Courtland	near	Town	J. T. Moore	D			125	2	125		
Courtland		Williams & Ketcham	J. T. Moore	D			160	2			
Courtland		W. Shands					170	2			
Courtland	near	W. J. Sebrell		D			160				
Courtland	2 mi. S.	W. A. Howell	J. T. Moore	D	1909	15(?)	207	2			
Delaware	near	Seaboard Air Line	George Wilkins	M			175	2			
Franklin	½ mi. N.	Camp Manufacturing Co. (17 wells)		M		10	130	1½	130		
Franklin		J. L. Camp		O		70	190	2			
Franklin		R. H. B. Cobb									
Franklin		P. F. Darden					177	2			
Franklin		W. H. L. Goodman		O		22	154	2			
Franklin		Goodman & Barrett		O		22	142	2			
Franklin		O. W. Hayes		O		18	150	2			
Hugo	near	Farmers' Mfg. Co.	P. P. Ellis	D	1908		125	2	125	none	
Sands		T. H. Barrett	P. P. Ellis	D			222		222		
Sebrell	near	Tidewater Railway Co.	Sydnor Pump & Well Co.	O	1907	58	344	10			344
Storeys	near	J. T. Moore	J. T. Moore	O		55(?)					
Sedley	near	Philip Rogers	J. T. Moore	O		60	200	2½			
SPOTTSYLVANIA											
Fredericksburg	½ mi. NW	E. D. Cole	—Alexander	O	1902	50	152	2	150		150
SURRY											
Bacons Castle	near	W. A. Warren	A. L. Spandour		1896	84	460	4			80
Bacons Castle	4 mi. E.		A. L. Spandour		1894	22	400+	1½			
Dendron		Surry Lumber Co.			1888	125	386 315	6			
Homewood	2 mi. S.E.	W. F. Gray	Whitmore	M	1889	5	219	1½			
Homewood	½ mi. SW	W. F. Gray	Whitmore	M	1888	5	250	1½			
Homewood	1 mi. NW	W. F. Gray	Whitmore	M	1888	5	240	1½			

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
	St. Marys						
	St. Marys						
	St. Marys						
	St. Marys						
	St. Marys						
	St. Marys						
White sand	St. Marys		3			Soft	
	St. Marys						
	St. Marys						
Rock at 100 ft.							
Gravel	UpperCretaceous		3			Soft, sulphur	Drinking, fish pond
	UpperCretaceous						
White sand		32(?)	20			Soft	Domestic and stock
Sand	Chesapeake	+35	5			Soft	Domestic
White sand		+35?	20			Soft	Domestic and stock
		30(?)		8			
		30(?)		8			Household and stock
	Chesapeake (?)	37	7			Soft	Domestic
	Chesapeake (?)						
	Chesapeake (?)						
	Chesapeake (?)						
	Chesapeake (?)		small				
	Chesapeake (?)		24				
	Chesapeake (?)	32(?)					
	Chesapeake (?)						Domestic
White sand	Chesapeake (?)	+22					Drinking and stock
White sand	Chesapeake (?)	+26					Household
White sand							
White sand	Chesapeake (?)						
White sand	Chesapeake (?)	+23	2				
White sand	Chesapeake (?)	+23	2				
White sand	Chesapeake (?)	+22	5				Household
White micaceous sand	Upper Cret's (?)	45	2			Soft	Domestic
	Upper Cret's (?)	+45					No flow
Sand and gravel	Potomac	+43			106	Soft	Locomotives
	Chesapeake (?)						No flow, abandoned
	Patuxent	+30					Medicinal and household
							No flow, never used.
		+30	10		63½	Soft	Drinking, making brick
							No flow, abandoned
Soft rock	Calvert	+35	2½		62½	Soft, sulphur	Household and stock, formerly boiler
	Calvert				64½		Domestic and stock
	Calvert						

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
SURRY—Cont.						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Homewood	near	W. F. Gray	A. L. Spandour	M	1887	6	330(?)	1½			
Homewood	at	W. F. Gray	A. L. Spandour	M	1887	6	330(?)	1½			
WARWICK											
Leehall	near	J. Clements	S. H. Fellterholf	D	1906	43	460	2			
Menchville				M		25	300				
Mulberry Is.	S.	Phillip Lederhor	H. E. Shimp	O	1904	5	384	2–1			
Mulberry Is.	at	P. H. Wright	H. E. Shimp	O	1900	10	370	1	370	200 275	
Newport News		Old Dominion Land Co.		O		30	582				
Newport News		Old Dom. Brewing Co.	H. E. Shimp	D	1907		500	2			
Tidewells	near N.	C. E. Daiger	Chas. H. Jones	O	1896	8	225	2			[illegible]
Tuckerhill	3 mi. E.	J. R. Dor Passor (15 wells)	Chas. H. Jones	O	1898–1906	5–15	235–250	1½	225–235		[illegible]
Tuckerhill	3 mi. S.E.	J. R. Dor Passor	Chas. H. Jones	O	1903	1	90	1½	70		70
Tuckerhill	3 mi. S.E.	Chas. H. Jones	Chas. H. Jones	O			245	1½			[illegible]
Tuckerhill	3 mi. N.W.	Jas. S. Sydnor	Chas. H. Jones	O	1894	14	248	2	240	228	64
White Point	at	D. W. Allen	Jones & Allen	O	1896		240	1½	240		[illegible]
White Point	½ mi. S.	D. W. Allen	Chas. H. Jones	O	1898		240	1½	240		[illegible]
White Point	½ mi. N.E.	G. L. Wilson	Chas. H. Jones	O	1901	10	216	2	210	12, 20	[illegible]
Wilkerson	⅛ mi. N.	Gouldman Bros.					240	1½			
Wilkerson	1 mi. W.	L. C. Hardy	Chas. Pfeil	O	1904	20	248	1½			
Wilkerson	1 mi. W.	L. C. Hardy	E. Gouldman	O		30	470				
Wilkerson	near	W. S. Wilkerson	Chas. Pfeil	O	1903	4	235	1½			
Wilkerson	near	W. S. Wilkerson	Chas. Pfeil	O	1906	7	235	1½			
Zacata	3 mi. W.	W. E. Goodridge	Chas. H. Jones	O	1904	12½	160	2–1¼	158		45
Zacata	3 ½ mi. E.	Westmoreland Oyster Packing Co.	Chas. H. Jones	O	1900	3½	158	2–1¼	152		[illegible]
WESTMORELAND											
Bealer	near	Beale & Biddle	Chas. Jones	O	1899	2	175	1½	172		
Chiltons		Hardwick & Sanford	Chas. Jones	O	1903	10	155	1½	155		
Coles Point		E. C. Barnes					220	1½			
Coles Point	¼ mi. S.E.	John Bronson	Chas. Jones	O	1896	5	216	1½	205		85
Coles Point		S. W. Godman					207				
Coles Point	¼ mi. E.	Wm. Mayo	L. Rude	D	1907	15	360	1½	350	230	[illegible]
Colonial Beach	near N.W.	Theodore Barnes			1902	10	240	1	240		
Colonial Beach	½ mi. S W	Mrs. Bell		O	1890	9	200				
Colonial Beach	⅛ mi. N.E.	M. A. & E. S. Bentley		O	1894	10	200	1¼	200		
Colonial Beach	½ mi. S W	D. C. & L. J. Connelly	Chas. Pfeil		1904	10	214	1½			
Colonial Beach	¼ mi. N.	Colonial Beach Hotel (5 wells)		M	1904	12	212	1½	212		
Colonial Beach	½ mi. N.	Mrs. C. A. Eckstein	Chas. Pfeil	O	1898	6	196	1¼	196		
Colonial Beach	1 mi. S.	J. C. Felch	Chas. Pfeil	M	1905	10	224	1½			
Colonial Beach	⅛ mi. S W	E. Gouldman	E. Gouldman	O	1904	15	245	2	225		[illegible]
Colonial Beach		John Hammond	Chas. Pfeil	O	1903	6	200⅓	2	200⅓		[illegible] [illegible]
Colonial Beach	near W	T. B. Harrison		O	1896	12	200	1			

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
			4		63½		
	Calvert	+35	3				
		+30					Domestic and stock
							Never used, no flow
	Calvert (?)	+22	2		67	Alkaline	Drinking, stock, boats
Rock	Calvert (?)	+29	¾		63½	Alkaline	Domestic stock and medicinal
		+20					Never used, no flow
							Abandoned
Sand	Calvert	flows	1			Soft	House and stock
	Calvert		½-1		62-63		Household and stock
Gravel	St. Marys		3			Ferruginous	
	Calvert						Household and stock
Rock and sand	Calvert		2			Soft	Household and stock
Sand	Calvert		1⅛		68		
Sand	Calvert				61		
	Calvert		1			Soft	Canning factory
	Pamunkey						
	Pamunkey	+22					Domestic and stock
							No flow, not used
	Pamunkey		3½		62		Drinking and public
	Pamunkey		1⅝		61		Hotel
Sand	Pamunkey					Soft	Domestic and stock
Sand	Pamunkey		2			Soft	Domestic and stock
	Calvert		8				General
	Calvert					Soft	Tomato cannery and domestic
	Calvert	+12	3				
	Calvert		1½			Sulphur	Domestic and stock
	Calvert	flows					
Rock cays 210-230, sand	Pamunkey	+30	6			Soft	House and stock
	Pamunkey				61		Household
	Pamunkey		⅞		61		Household
	Pamunkey		¼				Hotel
	Pamunkey	flows	2			Soft	Household
	Pamunkey		5	15			All
	Pamunkey		½		61		Household
	Pamunkey		⅛		61		Household
Thin rock at 220, chocolate col'd clay	Pamunkey	+19	3			Soft	Household
Sand	Pamunkey		4-1½		62¾		Ice manufacture
	Pamunkey		½		64½		Household

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
WESTMORELAND —Cont.						Ft.	Ft.	In.	Ft.	Ft.	Ft.
Colonial Beach..	2 mi. SW	L. W. Jett	L. W. Jett	O	1901	15	230	1½	222	75	22
Colonial Beach..	W.	Dr. A. E. Johnson	....	..	1899	10	225	....	....	....	....
Colonial Beach..	W.	D. Knowlton	C. Jones	O	1902	20	250	....	....	....	....
Colonial Beach..	½ mi. N.	M. E. Loeffler	E. Gouldman	O	1906	20	244	1¼	200	....	....
Colonial Beach..	¼ mi. SW	Mutual Ice Co	R. Rude	D	1909	5	422	1½	415	230	....
Colonial Beach..	S. W.	Maguinnis Estate	——Graves	M	1898	9	214	1½	....	....	....
Colonial Beach..	2 mi. SW	O. L. Massey	....	M	1900	....	225	1½	....	....	....
Colonial Beach..	near N.	A. Mensch	Chas. Pfeil	D	....	6	204	1¼	204	....	....
Colonial Beach..	near	——Pierson	Chas. Pfeil	D	1897	8	208	1½	....	....	....
Colonial Beach..	near N.	Reh & Ninde	....	O	1900	10	225	1	225	....	....
Colonial Beach..	½ mi. W.	John Sebastian	E. Gouldman	D	....	....	80	1½	....	....	....
Colonial Beach..	½mi.NW	J. R. Sutton	Chas. Pfeil	O	1905	18	230	1½	230	....	....
Colonial Beach..	1 mi. S.	J. M. Taylor	——Roane	O	1896	4	210	2	....	....	59
Colonial Beach..	N.	J. W. Thompson	....	O	1904	20	242	1¼	242	....	....
Colonial Beach..	W.	Town	——Roane	M	....	11	225	....	....	....	....
Colonial Beach..	1 mi. S.	Town	....	M	1902	8½	247	1½	....	....	....
Colonial Beach..	near S.W.	F. W. Walcott	Johnson	O	1888	10	276(?)	1½	230	none	80
Colonial Beach..	S. W.	C. W. Welles	Chas. Pfeil	O	1904	8	214	1½	214	70	86
Colonial Beach..	½mi.S W	C. W. Welles	Chas. Pfeil	O	1900	8	214	1½	214	....	....
Erica	1 ½ mi. E.	N. T. Ames	Chas. Jones	O	1902	7	187	1½	187	....	100
Erica	1½mi.SW	Paul Detrick	....	M	1900	18	327	1½	....	....	....
Erica	near S.W.	E. T. Barnett	Chas. H. Jones	O	1903	15	335	3	....	....	....
Hague	3 ½ mi. N.	G. F. Brown (3 wells)	L. Rude	O	1894	8	247	2	....	....	247
Hinnom	....	J. B. Hall	Chas. H. Jones	O	1897	2	144	1½	144	....	44
Hinnom	near	Hardwick & Sanford	Chas. H. Jones	O	1903	8	154	1½	144	....	....
Kinsale	½mi.N.E.	G. P. Bailey	G. P. Bailey	O	1894	8	238	1½	235	....	226
Kinsale	....	G. P. Bailey	Chas. H. Jones	..	1901	6	238	1½	235	....	40
Kinsale	....	G. P. Bailey	Chas. H. Jones	..	1903	6	238	1½	235	....	40
Kinsale	¼mi.N.E.	Dameron & Courtney	L. Rude	O	1893	4	275	1½	....	....	120
Kinsale	½mi.N.E.	S. B. Hardwick	....	O	1892	6	245	1½	....	....	100
Kinsale	⅜mi.N.E.	V. B. Hardwick	....	O	1902	8	245	1½	....	....	40 220
Kinsale	1 mi. N.	Chas. Taylor	Chas. H. Jones	O	1903	7	260	1½	260	190	140
Maple Grove..	1 mi. E.	Floyd Omohundro	E. Gouldman	O	1905	60	300	1½	....	....	40
Meter	....	B. H. Bronson	....	..	....	....	240	....	....	....	....
Meter	⅓ mi. W.	H. L. Shepard	Chas. H. Jones	O	1896	6	227	1	....	....	....
Mount Holly....	½ mi. E.	S. J. Hopkins	Chas. H. Jones	O	1897	4	135	2	135	....	25
Mount Holly....	near	Nominie Packing Co.	Chas. H. Jones	O	1903	9	153	1½	153	144	80
Oak Grove	2mi.S.W.	Andrew Flanmer	Shaw & Roane	O	1897	....	664	1½	300	....	110
Oak Grove	....	Andrew Flanmer	....	O	....	....	63	48	....	....	....

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
Sand	Pamunkey	+35			61		Household and public
	Pamunkey		½		60½		Household
	Pamunkey		⅛		62		Household
	Pamunkey	15	¼				Hotel
White sand	Potomac		6				Making ice
	Pamunkey	+15	1¼		64½	Soft, sulphur	Household
	Pamunkey					Soft, sulphur	Household
Rock	Pamunkey		2			Soft, sulphur	Hotel
	Pamunkey					Soft, sulphur	Flow stopped
	Pamunkey		½		61	Soft, sulphur	Hotel and store
	Pamunkey					Soft, sulphur	
	Pamunkey					Soft, sulphur	Flow stopped, not used
	Pamunkey	+12	1			Soft, sulphur	Household
	Pamunkey		½		63	Soft, sulphur	Household
	Pamunkey		⅛		63	Soft, sulphur	Public
	Pamunkey		⅓		61	Soft, sulphur	Public
Black sand	Pamunkey	+18 +10	4			Soft, irony	Domestic and hotel
Red clay	Pamunkey	+14	¾		62	Soft, sulphur	Household
Clay	Pamunkey	+6	1			Soft	Household
Gravel	Pamunkey	+9	¾			Soft, sulphur	Household and stock
	Pamunkey		2¼		65	Soft	Household and stock
Sand	Pamunkey	+12				Irony	Household and stock
Rock at 200 feet.	Pamunkey					Soft, sulphur	Household and stock
White sand	Chesapeake		1½		63¾		
	Chesapeake	+20	18			Soft	Canning factory
Rock	Chesapeake	+18	4				Steamboat and canning
	Chesapeake	+16	4		64		Canning factory and steamboat dock
	Chesapeake		4				
Sand	Chesapeake	+18	7			Soft	Canning factory and drinking
	Chesapeake	+18	4				Canning factory and drinking
Sand	Chesapeake	+15	8				Canning factory and drinking
Sand	Chesapeake		5		61	"Slightly hard"	Household and stock
White sand		+20					Not used, no flow
		flows				Soft, slightly sulphur	Domestic
Rock at 125 feet.	Chesapeake	flows	⅓		63	Soft, sulphur	Household and stock
Rock	Chesapeake	+18	2		63		
							No flow, never completed
	Chesapeake						Household

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

County and Postoffice	Direction and distance from postoffice	Owner	Driller	Authority	Date (approximately)	Elevation above mean high tide	Depth	Diameter	Depth to principal water bed	Depth to other water beds	Length of casing
						Ft.	Ft.	In.	Ft.	Ft.	Ft.
WESTMORELAND—Cont.											
Oak Grove	2 mi. W.	W. D. Wirt	Chas. Pfeil	O	1894	23	190	2	190	....	[illegible]
Potomac Mills	4 mi. N. E.	James Muse	F. K. Walcott	M	1900	22	280	3	280	....	....
YORK											
Grove	5 mi. S. W.	A. G. Harwood	H. E. Shimp	M	1903	30	429	2	429	none	[illegible]
Lackey	1 mi. N. E.	Mrs. K. Kirkwood	H. E. Shimp	M	1903	.....	450	1	450	300	....
Magruder	2 mi. N. E.	....	....	M	1890	2	226	1½	.....	....	....
Messick	2 mi. N. W.	S. J. Marynham	J. W. T. Robertson	..	1904	.....	90	....	.....	....	....
Oaktree	3 mi. E.	Edward Maynard	S. H. Felterholf	D	1905	11	367	2	.....	....	....
Yorktown	3 mi. N. W	G. B. Donnelly	H. E. Shimp and S. H. Felterholf	D	1903	2	429	2	.....	70	....
Yorktown	5 mi. N. W	——Squires	S. H. Felterholf	D	1906	6	358	2	.....	....	....
Yorktown	....	Am. Cem. & Eng. Co.	H. A. McTavish	M	1909	3	750	3	750	....	....
Williamsburg	4 mi. N.	....	S. H. Felterholf	..	1906	.....	408	2	.....	....	....

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
....	Pamunkey	flows	⅕	....	......	Soft	Domestic and stock
Rock at 80 ft. gravel	Pamunkey	flows	½	....	......	Soft	Domestic and stock
Gravel...........	Pamunkey	+20	....	....	......	Alkaline	Domestic, boiler
Gravel...........	Pamunkey	......	4½	....	......	Soft, alkaline	Domestic and stock
....	Chesapeake	+20	20	....	......	....	....
....	....	......	....	....	......	Sulphur	Domestic
....	Pamunkey	+25	1½	....	......	....	Household
Green rock	Pamunkey	+38	4	....	......	....	Household and stock
....	....	+28	3	....	......	....	Household and stock
....	....	+10	1	....	......	"Good"	....
....	....	+25	10-1	....	......	....	Drinking, &c.

TABLE 6—*Analyses and field assays (F) of water from springs.*

County and locality	Name of Spring	Owner	Source	Turbidity	Total solids	Organic and volatile matter	Silica (SiO_2)	Iron and aluminum oxides $(Fe_2O_3+Al_2O_3)$	Iron (Fe)
ALEXANDRIA									
Ballston	Powhatan		Granite		38.0		12.		.2
Glencarlyn	Erup Mineral	H. H. Young	Gravel		47.8	9.0			.1
CHARLES CITY									
Oldfield		A. M. Wheeler	Sand		73.17		17.4		.5
Oldfield		A. M. Wheeler	Sand		61.08		19.65		.5
CHESTERFIELD									
Bon Air	Beaufont	Beaufont Lithia Spring Water Co.	Granite		63.		16.		.5
Buckhead Springs	Buckhead Chloride Lithia	T. S. Wheelwright	Sand		43.		7.4		.1
Manchester	Bellfont Lithia		Granite		45.		14.		1.
Manchester	Fonticello Lithia	W. G. Taylor	Granite		46.		14.		1.5
Manchester	Lion Lithia	Virginia Lithia Springs Co.	Sand		28.1		10.		.11
Temples	Campfield Lithia	Campfield Lithia Water Co.			28.		5.3		.2
Swansboro	Holly Lithia	Holly Springs Co.	Sand and gravel		35.6		10.7		.9
Swansboro	Holly Lithia	Holly Springs Co.	Sand and gravel		35.4		11.2		.5
Wiseville	Rocky Run Lithia	David Adkins							1.1
ESSEX									
Meade	Sulphur	Chas. Tombs	Sand and iron crusts	.0					1.5
Meade	Sulphur	Chas. Tombs	Sand	.0					tr.
GLOUCESTER									
James Store		County	Marl	.0					.0
HANOVER									
Hanover Station		R. F. & P. Ry.	Sand	.0					
Ellerson		B. A. Taliaferro	Sand		19.		6.2		.6
HENRICO									
Barton Heights		Town	Marl and sand	.0	106.	42.			.6
East Richmond	Como Lithia	I. J. Hawkes	Sand and gravel		34.	tr.	5.4		.1
Elko		R. W. Swift	Sand	.0					tr.
Richmond		County	Sand	.0					
Richmond		Home Brewing Co.	Gravel		124.	16.			tr.

[a] Ammonium (NH_4), .069.
[b] Ammonium (NH_4), .016.
[c] Ammonium (NH_4), .013.
[d] Barium (Ba), .02.
[e] Barium (Ba), .008.
[f] Barium (Ba), trace.

TABLE 5 *(Continued)*—*Data of wells in Coastal Plain Province of Virginia.*

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
Sand	Pamunkey	+27?			61		Domestic
Sand	Pamunkey	+20					Domestic
Sand	Pamunkey	+25					Drinking and boiler
Blue sand	Pamunkey	+13	1⅔			Soft	Domestic
Sand	Pamunkey	+15					Domestic
Gravel, sand and shell	Columbia	±0				Hard	Boiler and domestic
Sand	Columbia (?)						Drinking
		+10				Irony	Not used
Gravel		+1½?			70		Domestic and stock
	Columbia (?)	+8				Hard	Domestic, stock and boiler
	Calvert (?)	+5				Alkaline, saline	
Fine micaceous sand		+28	[a]51		72	Saline	Drinking, washing
Gravel	Columbia		30			Salty	
Sand and gravel	Columbia	±0				Alkaline	Drinking, boiler
	Yorktown (?)	+4				Irony	Abandoned
Gravel	Columbia						
							No flow, abandoned
Sand	Columbia	+0		100			Locomotives, machine shops
Gravel and sand	St. Marys (?)	+1	10	80		Brackish	Boiler
							No flow, abandoned
							Town supply, making ice
Shells	Chesapeake (?)	−⅓				Good	Domestic and stock
	Columbia						Domestic
		±0					
	Columbia	+4					Domestic and stock
	Columbia (?)	+6	1⅓				Domestic and stock
	Chesapeake		2			Soft, slightly sulphur-bearing	Domestic
	Chesapeake		2				Domestic
	Chesapeake						Boats, domestic and drinking
Sand	Chesapeake	-6	¾			Soft, slightly sulphuretted	Drinking, etc.
Shells	Columbia					Hard	Domestic

TABLE 6 *(Continued)—Analyses and field assays (F) of water from springs.*

County and locality	Name of Spring	Owner	Source	Turbidity	Total solids	Organic and volatile matter	Silica (SiO_2)	Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$)	Iron (Fe)
JAMES CITY									
Williamsburg		Mrs. R. M. Smith	Marl	.0					.9
KING GEORGE									
Hickory Fork			Sand						tr.
KING WILLIAM									
Enfield		G. W. Scott	Sand	.0					.4
NEW KENT									
Whitehouse	Belmont Lithia	R. E. Richardson	Marl		221.		33.		4.7
NORFOLK									
	White Oak Mineral				146.		5.4		tr.
	Landale Mineral Spring		Sand		87.		5.3		[illegible]
PRINCE GEORGE									
Blair		David Dunlop		.0					tr.
Warwick Church		Warwick Church	Sand	.0					tr.
PRINCESS ANNE									
Waterway	Diamond		Sand						
SPOTTSYLVANIA									
Fredericksburg		Aqueduct Co.	Sand and gravel						
Fredericksburg	Gunnery	City	Sand and gravel	.0					tr.
Fredericksburg	Mint	City	Sand and gravel	tr.					
Fredericksburg	Silk Mill			.0	157.				[illegible]
SURRY									
Claremont		E. S. Collins	Marl	.0	207.	60.	39.		[illegible]
Claremont	Trepho Lithia	E. E. Harry	Sand	.0					1.6
Claremont	Trepho Lithia	E. E. Harry	Sand		573.		34.		[illegible]
SUSSEX									
Waverly	Cappahaunk		Marl	.0					1.
Waverly	Cappahaunk		Marl		293.		23.		.7
WESTMORELAND									
Kinsale		Chas. Taylor	Sand	.0					

*Also contains Barium (Ba), .15; Strontium (Sr), .10; Zinc (Zn), faint trace.

TABLE 6 *(Continued)—Analyses and field assays (F) of water from springs.*

	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Lithium (Li)	Arsenate radicle (AsO$_4$)	Phosphate radicle (PO$_4$)	Sulphate radicle (SO$_4$)	Carbonate radicle (CO$_3$)	Bicarbonate radicle (HCO$_3$)	Nitrate radicle (NO$_3$)	Iodine (I)	Bromine (Br)	Chlorine (Cl)	Total hardness as CaCO$_3$	Date	Analyst
...	......	much	......	....	......	....	......	......	......	>30	......	160.	....	....	....	9.5	140.	1906	S. Sanford (F)
...	......	little	......	....	......	....	......	......	......	tr.	......	30.	....	....	....	10.	......	1906	S. Sanford (F)
...	......	little	......	....	......	....	......	......	......	tr.	0.	18.	....	....	....	7.6	31.	1906	S. Sanford (F)
53	.16	34.	1.8	....	5.5	3.4	.01	......	.26	3.5	......	132.	tr.	....	....	2.7	......	....	W. H. Taylor
...	......	21.	2.8	....	14.	3.6	......	......	......	29.	......	55.	....	....	....	15.	......	....	W. H. Taylor
18	tr.	5.8	2.5	....	14.	1.3	.01	tr.	......	28	......	9.2	5.5	.009	tr.	18.	......	....	S. Sanford (F)
...	......	little	......	....	......	....	......	......	......	>30	......	42.	....	....	....	3.1	55.	1906	S. Sanford (F)
...	......	little	......	....	......	....	......	......	......	>30	......	42.	....	....	....	4.5	33.	1906	S. Sanford (F)
...	....	......	......	....	......	....	......	......	......	....	......	......	....	....	....	......	......	....	....
...	......	little	......	....	......	....	......	......	......	....	......	17	....	....	....	9.	10.	1906	S. Sanford (F)
...	......	little	......	....	......	....	......	......	......	>30	0	50	....	....	....	27	......	1906	S. Sanford (F)
...	......	......	......	....	......	....	......	......	......	....	0	23	....	....	....	35.	18	1906	S. Sanford (F)
...	......	6.4	......	....	......	....	......	......	......	....	......	29.	....	....	....	......	24.	1905	E. C. Levy
...	......	35.	7.6	....	23.	....	......	......	......	17.	10.	155.	.9	....	....	6.6	......	1906	E. B. Dole
...	......	some	......	....	......	....	......	......	......	>30	0.	180.	....	....	....	6.	140	1906	S. Sanford (F)
5	......	2.9	3.2	....	11.	2.1	.03	......	......	3,8	......	395.	....	....	....	3.5	......	1907	J. B. Weems
...	......	much	......	....	......	....	......	......	......	>30	......	305	....	....	....	7.5	220	1906	S. Sanford (F)
[illegible]	tr.	93.	1.5[a]	....	5.4	2.9	.19	.034	.12	1.6	143.	......	....	tr.	tr.	11.	......	....	Froebling & Robinson
...	......	0.(?)	......	....	......	....	......	......	......	>30	......	32.	....	....	....	14.	13.	1906	S. Sanford (F)

TABLE 7—*Analyses and field assays (F) of well water from Columbia formations.*

Locality	Owner	Type of well	Depth (feet)	Total solids	Organic and volatile matter	Silica (SiO_2)	Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$)
ACCOMAC							
Accomac	County	dug	26				
Accomac	G. L. Doughty	driven	34				
Accomac	B. T. Melson	drilled	50				
Belinda	M. E. Hall	drilled	68				
Chincoteague	D. J. Whealton	driven	14				
Fox Island	W. Ellinger	driven	32				
Fox Island	W. Ellinger	driven	32				
Franklin City	James Chapman	driven	70				
Franklin City	N. Y. P. & N. R. R.	driven	80	250.			
Greenbackville	I. T. Sharpley	driven	40				
Greenbackville	Elihu Tull	driven	34				
Hallwood	N. Y. P. & N. R. R.					14.	
Nandua	J. R. Henderson	drilled					
Nandua	A. T. L. Kusian	drilled	75				
New Church							
New Church							
Onancock	Town	driven					
Onancock	Town	dug and driven					
Onancock	M. L. Hurst	driven	36				
Pungoteague	S. T. Taylor	driven	62				
Tasley	N. Y. P. & N. R. R.	dug	12	71			
Tasley	N. Y. P. & N. R. R.	driven		112.		6.8	
Wachapreague	W. E. Brittingham	driven	12				
CAROLINE							
Bowling Green	Gill	dug	35				
Bowling Green	Town	dug					
Bowling Green	R. P. Vincent	dug					
Bowling Green	Dr. A. Webb	dug					
Delos		dug	20				
Messaponax		dug	22				
Port Royal	Arkins	dug	25				
CHARLES CITY							
Charles City	Mrs. Major	dug	40				
Shirley	H. I. Saunders	driven	30				
CHESTERFIELD							
Manchester	Chesterfield Laundry						
ELIZABETH CITY							
Hampton	Hampton Institute						
Hampton	Hampton Institute			524.			
Hampton	Hampton Mfg. Co.	dug					
Hampton	Hampton Roads Ry. & Elect. Co.	dug					
Hampton	City	dug	22				
ESSEX							
Center Cross		dug	22				
Tappahannock	Jas. Jackson	driven	18				
GLOUCESTER							
Achilles							
Bridges	Thos. Bridges	driven	12				

TABLE 5 *(Continued)—Data of wells in Coastal Plain Province of Virginia.*

Principal water beds		Head of water above mean high tide	Yield per minute		Temperature	Quality	Uses
Material	Group or formation		Flow	Pump			
		Ft.	Gal.	Gal.	°F.		
	Calvert		1½				
	Calvert	flows					
	Calvert	+12	¾		63		Drinking
	Calvert	+10	1½				Canning factory and domestic
	Calvert		7½				Canning factory and domestic
	Calvert		1				Domestic
	Calvert		1				Domestic
Rock	Calvert	+8	3			Soft, slightly sulphur	Drinking
	Calvert	+6	2				Domestic
Sand	UpperCretaceous	+35	45			Soft	Boiler at fish factory
Sand	UpperCretaceous	+30	75				
	Calvert (?)		2			Soft	
Sand	UpperCretaceous	+35	40			Soft, alkaline	Boats, domestic and stock
	UpperCretaceous		10			Soft, alkaline	Boats, domestic and stock
Sand	Calvert (?)		3			Soft, sulphur	Drinking
	Calvert		1¼		62½		Not used
Gravel and sand	Calvert						
Gravel			3-18				
	Calvert		17				
Porous rock	Calvert	+14			62	Slight sulphur	Boilers, domestic
Rock at 500							
Black sand	UpperCretaceous	+40	45			Soft, alkaline	Fish factory boiler
	Calvert		1, ⅛			Soft	Household and stock
	Calvert	+12				Soft, alkaline	Washing oysters
Sand	UpperCretaceous		33	30		Soft	Fish factory, boiler and drinking
	UpperCretaceous		45				
	UpperCretaceous		18				
Sand	UpperCretaceous	+38	50			Soft	Fish factory boiler
Sand and gravel	UpperCretaceous	+25	35			Soft, alkaline	Fish factory boiler and drinking
Sand	UpperCretaceous	+38	40	200		Soft	Washing, drinking
	UpperCretaceous						
	Columbia					Irony	Washing, etc., no longer used
							No flow, abandoned
Sand	Upper Cret's (?)	+25?	75		76	Saline, sulphur	Part of public supply

TABLE 7 *(Continued)—Analyses and field assays (F) of well water from Columbia formations.*

Locality	Owner	Type of well	Depth (feet)	Total solids	Organic and volatile matter	Silica (SiO_2)	Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$)
GREENVILLE							
Emporia	Emporia Mfg. Co.	bored and driven	22				
HANOVER							
Ellerson	R. L. Acree	dug	42				
Hanover C. H.	County	dug	25				
HENRICO							
Ginter Park	S. H. Hawes	dug	32	62.	.17	8.0	
Richmond	Lewis Ginter L. & I. Co.	dug	27				
Richmond	Rosenecgk Brewing Co.	dug	10	110.	40.	19.	
ISLE OF WIGHT							
Moonlight	Dr. Wells	dug	10				
JAMES CITY							
Williamsburg[a]	H. Johnson	dug	35				
KING GEORGE							
King George	County	dug	30				
Passapatanzy		dug	20				
KING AND QUEEN							
Cumnor	C. C. Vaughan	dug	30				
MATHEWS							
Mathew C. H.		dug	10				
MIDDLESEX							
Churchview		dug	22				
NORFOLK							
Berkley	Portsmouth, Berkeley & Suffolk Water Co.						
Berkley	Portsmouth, Berkeley & Suffolk Water Co.	driven	20-85				
Buell[a]	Pocomoke Guano Co.	driven	86	600.	301.		
Port Norfolk	Air Line Mfg. Co.	driven		170.	53.	7.7	
Port Norfolk	Air Line Mfg. Co.	driven	38				
Port Norfolk	Portsmouth & Norfolk Tract. Co.	driven	16-50	210.	72.	14.	7.
Port Norfolk	Seaboard Air Line R. R.	driven	60	280.	15.	40.	2.9
Port Norfolk	Seaboard Air Line R. R.	driven	old wells	275.[b]	7.7	44.	.36
Port Norfolk	Seaboard Air Line R. R.	driven	60	218.	8.	42.	3.
Port Norfolk	Seaboard Air Line R. R.	driven	new wells	[b]	10.	43.	tr.
Portsmouth	United States	driven	35	236.	85.	9.9	5.8
Norfolk	Imperial Co.			1,294.	24.	34.	
NORTHAMPTON							
Cape Charles	Heckle & Kellogg	driven		195.			
Cape Charles	N. Y. P. & N. R. R.	drilled	90			20.	
Cape Charles	N. Y. P. & N. R. R.	driven	18	251.		17.	
Cape Charles	N. Y. P. & N. R. R.	driven	12	226.			
Cape Charles	N. Y. P. & N. R. R.	drilled	90			21.	5.1
Cape Charles	N. Y. P. & N. R. R.	drilled	97	218.			

[a] Water may come from Chesapeake (Miocene) sand.

[b] Sample taken after prolonged pumping.

TABLE 7 *(Continued)—Analyses and field assays (F) of well water from Columbia formations.*

Iron (Fe)	Manganese (Mn)	Aluminum (Al)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Carbonate radicle (CO₃)	Bicarbonate radicle (HCO₃)	Sulphate radicle (SO₄)	Nitrate radicle (NO₃)	Chlorine (Cl)	Total hardness as CaCO₃	Date	Analyst
....	....	....	....	....	....			....	....	....	....	....	....	1904	H. Bentley Smith Co.
0.5	....	....	little	....	....			0.	16.	0.	....	6.	21.	1906	S. Sanford (F)
tr.	....	....	little	....	....			0.	22.	tr.	....	31.	41.	1906	S. Sanford (F)
1.7	....	....	5.4	4.6	.9	tr.		1.4	....	tr.	31.	7.		1906	Froehling & Robertson
tr.	....	....	0.(?)	....	....			0.	12.	>30.	....	8.	18.	1906	S. Sanford (F)
....	....	....	5.4	.56	13.	....	....	....	....	....	....	31.		1904	H. Bentley Smith Co.
2.(?)	....	....	little	....	....	....	....	....	14.	tr.	....	11.		1906	S. Sanford (F)
0.	....	....	much	....	....	....	....	....	180.	tr.	....	46.		1906	S. Sanford (F)
....	....	....	little	....	....	....	....	0.	32.	0.	....	....	....	1906	S. Sanford (F)
tr.	....	....	little	....	....	....	....	0.	7.3	....	....	14.	8.	1906	S. Sanford (F)
tr.	....	....	little	....	....	....	....	0.	23.	little	....	25.	32.	1906	S. Sanford (F)
tr.	....	....	mod.	....	....	....	....	....	40.	mod.	....	50.	75.	1906	S. Sanford (F)
tr.	....	....	little	....	....	....	....	0.	24.	0.	....	30.	23.	1906	S. Sanford (F)
.10	....	....	....	....	....	....	....	12.	....	20.	....	17.	35.	....	....
tr.	....	....	....	....	....	....	....	....	25.	tr.	....	15.	35.	1906	S. Sanford (F)
....	....	....	74.	31.	50.	....	....	292.	....	....	....	78.	....	....	Sparrows Point Boiler Compound Co.
....	....	....	27.	4.3	7.	....	....	28.	....	18.	....	24.	....	1905	H. Bentley Smith Co.
2.5(?)	....	....	little	....	....	....	....	....	64.	little	....	28.	56.	1906	S. Sanford (F)
....	....	....	21.	7.2	....	....	....	54.	....	49.	....	....	....	1906	Sparrows Point Boiler Compound Co.
....	....	....	35.	6.3	45.	....	....	78.	....	7.5	tr.	50.	....	1906	Froehling & Robertson
....	....	....	32.	6.	49.	....	....	83.	....	4.8	tr.	48.	....	1906	
....	....	....	38.	6.9	18.	....	....	73.	....	2.3	tr.	26.	....	1906	Froehling & Robertson
....	....	....	34.	8.3	18.	....	....	73.	....	3.2	tr.	25.	....	1906	
....	....	....	36.	3.4	....	....	....	31.	....	32.	....	....	....	1906	Sparrows Point Boiler Compound Co.
1.3	....	....	11,410.	42.	310.	....	....	187.	....	8.1	tr.	574.	....	1906	Froehling & Robertson
....	....	....	....	....	....	....	....	....	....	0.	....	48.	....	1905	York Mfg. Co.
1.2	....	.9	50.	67.	....	....	....	....	350.	3.4	....	1.7	....	....	....
3.6	....	27.	31.	55.	....	....	....	....	124.	14.	....	3.4	....	....	Baldwin Locomotive Works
....	....	....	much	some	....	....	....	....	....	much	.70	35.	....	1899	C. B. Dudley
....	....	....	6.5	2.2	....	....	....	....	....	5.3	....	20.	31.	....	Baldwin Locomotive Works
....	....	....	much	little	....	....	....	much	....	little	....	21.	....	1899	C. B. Dudley

TABLE 7 *(Continued)—Analyses and field assays (F) of well water from Columbia formations.*

Locality	Owner	Type of well	Depth (feet)	Total solids	Organic and volatile matter	Silica (SiO_2)	Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$)
NORTHAMPTON—Cont.							
Eastville	N. Y. P. & N. R. R.	......	......	......	......	8.5	......
Eastville	N. Y. P. & N. R. R.	......	10	190.	......	......	......
Eastville	County	driven	40	......	......	......	......
Exmore	N. Y. P. & N. R. R.	......	12	144.	......	......	62.
Exmore	N. Y. P. & N. R. R.	driven	18	......	......	22.	4.8
Exmore	N. Y. P. & N. R. R.	driven	12(?)	87.8	......	8.5	......
Exmore	N. Y. P. & N. R. R.	driven	30	......	......	33.	8.2
NORTHUMBERLAND							
Heatsville	J. E. Nelms	dug	45	......	......	......	......
PRINCESS ANNE							
Waterway	Norfolk County Waterworks	driven	30	115.	51.	......	......
Virginia Beach	Walker	driven	17	......	......	......	......
Waterway	Norfolk County Waterworks	driven	......	......	......	......	......
PRINCE GEORGE							
Claremont	......	......	......	......	......	......	......
Garysville	H. C. Browning	dug	25	......	......	......	......
SURRY							
Bacon's Castle	M. Bell	dug	28	......	......	......	......
Dendron	E. Jones	driven	25	......	......	......	......
Homewood	W. F. Maddera	dug	30	......	......	......	......
SUSSEX							
Wakefield	Baine Peanut Co.	dug	12	389.	180.	10.	......
Wakefield	E. W. Brittle	driven	20	......	......	......	......
Wakefield	S. Parr	dug	16	......	......	......	......
Waverly	Waverly Peanut Co.	dug	16	65.	4.4	10.	......
Waverly	J. D. Gray	driven	35	......	......	......	......
WESTMORELAND							
Kinsale	Hotel	dug	......	......	......	......	......
Leedstown	Jas. Baxter	dug	20	......	......	......	......
Oak Grove	A. Flanmer	dug	63	......	......	......	......
Potomac Mills	John Barrack	dug	27	......	......	......	......

TABLE 7 *(Continued)—Analyses and field assays (F) of well water from Columbia formations.*

Iron (Fe)	Manganese (Mn)	Aluminum (Al)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Nitrate radicle (NO_3)	Chlorine (Cl)	Total hardness as $CaCO_3$	Date	Analyst
1.2	....	.9	17.	54.	......	....	....	......	77.	8.5	......	1.7	......	....	Baldwin Locomotive Works
little	....	....	some	much	......	....	....	......	....	much	......	85.	......	1899	C. B. Dudley
0.	....	....	little	......	......	....	....	......	13.	55.	......	40.	67.	1906	S. Sanford (F)
much	....	....	some	much	......	....	....	......	....	much	......	43.	......	1899	C. B. Dudley
....	....	....	3.1	1.7	......	....	....	......	....	3.8	......	14.	25.	....	....
1.2	....	.9	6.	52.	......	....	....	......	....	17.	......	1.7	......	....	Baldwin Locomotive Works
....	....	....	4.8	3.	......	....	....	......	....	7.8	......	13.	34.	....	Baldwin Locomotive Works
....	....	....	....	......	......	....	....	0.	30.	......	......	30.	70.	1906	S. Sanford (F)
....	....	....	....	......	......	....	....	......	....	......	.75	8.	128.	1907	Booth, Garrett & Blair
tr.	....	....	little	......	......	....	....	......	26.	>80.	......	74.	50.	1906	S. Sanford (F)
tr.	....	....	little	......	......	....	....	......	8.	>80.	......	17.	42.	1906	S. Sanford (F)
0.	....	....	much	......	......	....	....	0.	110.?	0.	......	11.	97.	1906	S. Sanford (F)
4.5(?)	....	....	....	......	......	....	....	......	100.	>80.	......	11.	55.	1906	S. Sanford (F)
tr.	....	....	mod.	......	......	....	....	0.	23.	0.	......	95(?)	70.	1906	S. Sanford (F)
....	....	....	0.(?)	......	......	....	....	......	12.	0.	......	5.	41.	1906	S. Sanford (F)
.5	....	....	little	......	......	....	....	......	23.	0.	......	10.	38.	1906	S. Sanford (F)
....	....	....	21.	......	......	....	....	24.	....	11.	......	93.	......	1904	H. Bentley Smith Co.
....	....	....	little	......	......	....	....	......	81.	0.	......	22.	55.	1906	S. Sanford (F)
tr.	....	....	0.(?)	......	......	....	....	......	14.	0.	......	22.	48.	1906	S. Sanford (F)
....	....	....	10.	2.2	6.1	....	....	10.	....	2.1	......	20.	......	1904	H. Bentley Smith Co.
tr.	....	....	little	......	......	....	....	0.	16.	0.	......	12.	11.	1906	S. Sanford (F)
....	....	....	....	......	......	....	....	0.	35.	......	......	35.	37.	1906	S. Sanford (F)
tr.	....	....	much	......	......	....	....	0.	62.	>80.	......	20.	......	1906	S. Sanford (F)
tr.	....	....	much	......	......	....	....	0.	21.	much	......	31.	42.	1906	S. Sanford (F)
tr.	....	....	little	......	......	....	....	......	31.	......	......	26.	13.	....	S. Sanford (F)

TABLE 8—*Analyses and field assays (F) of well water from Chesapeake formations.*

Locality	Owner	Type of well	Depth (feet)	Total solids	Organic and volatile matter	Silica (SiO_2)	Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$)	Iron (Fe)
ACCOMAC								
Accomac[a]	B. T. Gunter	drilled	122.					2.
Accomac[a]	L. L. Tiffany	drilled	100.					tr.
Cashville[a]	Susan A. Tiffany	drilled	100.					tr.
Franklin City[a]		drilled	80.	250.				little
Harborton[a]	Allen & Lennau	drilled	140.					tr.
Pungoteague	S. W. Ames	drilled	210.	250.		45.		.1
CHARLES CITY								
Malvern Hill[b]	G. M. Gill	bored	70.					1.
Wilcox Wharf[b]	T. W. Hubbard	dug	48.	333.	3.1	34.		.75
ESSEX								
Bowler's Wharf	Donaldson & Schultz	drilled						
Bowler's Wharf	Claybrooke & McNeal Packing Co.	drilled	165.					tr.
Center Cross	C. F. Kriete	drilled	190.					tr.
Tappahannock	B. B. Brockenbrough	drilled	272.					tr.
Tappahannock	R. T. Cauthorn	drilled	275.	494.	48.			
Ware's Wharf	W. L. Ware	drilled	170.					tr.
GLOUCESTER								
Allmondsville	W. W. Allmond	drilled	270.					0.
Freeport	E. C. Farinholt	drilled	330.					.8
Freeport	R. H. Farinholt	drilled	338.					
Gloucester C. H.	Town	dug	30.					tr.
HENRICO								
Elko	E. J. Furman	driven	35.					1.
ISLE OF WIGHT								
Day's Point	J. A. Morgart	drilled	383.	434.		12.		.19
Shoalbay	Dr. Wm. D. Turner	drilled	226.	786.	15.	18.		.8
Smithfield	Smithfield Mineral Water Co.	drilled	300.	566.	.94	10.5		.22
Zuni	Town	drilled	161.					tr.
Zuni		drilled				16.2		.28
JAMES CITY								
Croaker	Wilbur H. Davis	drilled	200.	521.		21.		
Jamestown	C. F. Ayers	drilled	300.					tr.
Jamestown	Association for the Preservation of Virginia Antiquities	drilled	267.					tr.
Williamsburg	Marshall Estate	drilled	285.	523.		21.		tr.
Williamsburg	Galba Vaiden	drilled	276.	662.	40.			
Williamsburg	Mrs. R. M. Smith	drilled		185.		1.1		
Williamsburg	Mrs. R. M. Smith	drilled						3.0
Williamsburg	Eastern State Hospital	drilled	286.	553.		28.		tr.
KING GEORGE								
King George	Edward Hunter	dug	45.					tr.
KING WILLIAM								
West Point	Denmead Bros.	drilled	105.					tr.
West Point	Southern Railway	drilled	165.	927.		25.		.11
KING AND QUEEN								
Chain Ferry	Wm. Blake	drilled	165.					tr.
LANCASTER								
Irvington	W. A. Dameron & Bro.	drilled	330.					tr.

[a] May be in Columbia beds.
[b] Source of main supply uncertain.
[c] Also ammonium radicle (NH_4), .39; borate radicle (B_2O_7), trace.
[d] Biborate radicle (B_4O_7), 3.5
[e] Ammonium radicle (NH_4), 0.7; borate radicle (B_2O_7), trace.

TABLE 8 *(Continued)—Analyses and field assays (F) of well water from Chesapeake formations.*

Aluminum (Al)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Phosphate radicle (PO_4)	Nitrate radicle (NO_3)	Bromine (Br)	Iodine (I)	Chlorine (Cl)	Total hardness as $CaCO_3$	Date	Analyst
....	....	much	....	....	....	....	....	140.	tr.	....	....	....	....	12.	91.	1906	S. Sanford (F)
....	....	much	....	....	....	....	0.	124.	0.	....	....	....	....	11.	87.	1906	S. Sanford (F)
....	....	much	....	....	....	....	0.	170.	0.	....	....	....	....	11.	65.	1906	S. Sanford (F)
....	....	much	some	....	....	....	much	....	little	....	.8	....	....	14.6	....	1893	C. B. Dudley
....	....	some	....	....	....	....	0.	90.	....	....	....	....	....	38.	56.	....	S. Sanford (F)
....	....	25.	11.	32.	14.	....	0.	218.	1.6	....	3.6	....	....	12.	....	1906	R. B. Dole
....	....	tr.	....	....	....	....	....	115.	0.	....	....	....	....	27.	35.	1906	S. Sanford (F)
.5	....	2.5	.5	122.	....	....	tr.	313.	7.7	....	.1	....	....	4.3	....	1906	R. B. Dole
....	....	....	....	....	....	....	0.	200.	>25.	....	....	....	....	8.6	56.	1906	S. Sanford (F)
....	....	mod.	....	....	....	....	0.	150.	tr.	....	....	....	....	4.2	50.	1906	S. Sanford (F)
....	....	mod.	....	....	....	....	0.	205.	....	....	....	....	....	....	65.	1906	S. Sanford (F)
....	....	0.	....	....	....	....	12.	410.	>30.	....	....	....	....	5.8	7.3	1906	S. Sanford (F)
....	....	....	....	....	....	....	....	....	35.	....	0.	....	....	2.	25.	....	S. Sanford (F)
....	....	little	....	....	....	....	tr.	230.	>30.	....	....	....	....	3.	19.	1906	S. Sanford (F)
....	....	little	....	....	....	....	22.	402.	10.	....	....	....	....	106.	....	1906	R. B. Dole (F)
....	....	tr.	....	....	....	....	12.	680.	tr.	....	....	....	....	25.	3.2	1906	S. Sanford (F)
....	....	tr.	....	....	....	....	12.	670.	tr.	....	....	....	....	30.	8.	1906	S. Sanford (F)
....	....	much	....	....	....	....	0.	75.	>30.	....	....	....	....	147.	100.	1906	S. Sanford (F)
....	....	much	....	....	....	....	0.	190.	little	....	....	....	....	4.2	110.	1906	S. Sanford (F)
.58	.008	2.6	1.1	169.	6.2	.008	204.	....	11.	.85	....	.36	.0004	25.	....	1903	Froehling & Robertson
.64	tr.	3.9	1.4	193.	11.	tr.[c]	....	518.	1.6	.17	.75	.73	.77	17.	....	1907	Froehling & Robertson
1.2	tr.	7.	2.6	188.	6.1	....	175.	133.	9.	.13[d]	tr.	.012	.012	27.	....	1907	Froehling & Robertson
....	....	little	....	....	....	....	30.	370.	tr.	....	....	....	....	5.	14.	1907	S. Sanford (F)
....	....	2.76	4.1	140.	....	....	185.	....	12.5	....	....	....	....	4.	....	1909	N. S. Hill
....	....	2.9	tr.	130.	11.	tr.	....	350.	5.8	....	.2	....	....	2.7	10.	....	....
....	....	....	....	....	....	....	6.1	310.	....	....	....	....	....	135.	3.8	1906	S. Sanford (F)
....	....	....	....	....	....	....	14.	280.	tr.	....	....	....	....	57.	3.8	1906	S. Sanford (F)
....	....	7.2	2.7	185.	16.	....	179.	....	10.	....	....	....	....	108.	....	....	W. H. Taylor
....	....	12.	3.7	131.	....	....	198.	....	21.	....	....	....	....	149.	....	....	Keystone Chemical Co.
....	....	53.	2.2	107.	....	....	....	....	....	....	....	....	....	14.	....	....	Henry Froehling
....	....	much	....	....	....	....	....	360.	mod.	....	....	....	....	15.	480.	....	S. Sanford (F)
....	....	8.	4.3	191.	17.	....	188.	....	10.	....	....	....	....	107.	....	....	W. H. Taylor
....	....	mod.	....	....	....	....	0.	36.	>30.	....	....	....	....	170.	58.	1906	S. Sanford (F)
....	....	0.	....	....	....	....	0.	260.	>30.	....	....	....	....	3.	21.	1906	S. Sanford (F)
.86	....	4.8	47.	213.	14.	•	....	306.	307.	.6	tr.	.18	.04	6.7	....	....	Henry Froehling
....	....	tr.	....	....	....	....	....	230.	tr.	....	....	....	....	6.	14.	1906	(F.)
....	....	little	....	....	....	....	0.	480.	>30.	....	....	....	....	18.	10.	1906	S. Sanford (F)

TABLE 8 *(Continued)—Analyses and field assays (F) of well water from Chesapeake formations.*

Locality	Owner	Type of well	Depth (feet)	Total solids	Organic and volatile matter	Silica (SiO_2)	Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$)	Iron (Fe)
MIDDLESEX								
Urbanna	G. V. Wagenen	drilled	232.					
Dew	D. M. Nelson	drilled	297.					
NANSEMOND								
Everetts	T. J. Saunders	drilled	54.					tr.
NORFOLK								
Norfolk	Pocomoke Guano Co.	drilled	86.	600.				
NORTHAMPTON								
Bone Island		drilled	169.					1.5
Oyster	W. F. Travis	drilled	185.				tr.	
Sandy Island	Wharton Fisheries Co.	drilled	249.					tr.
Sandy Island	Wharton Fisheries Co.	drilled	249.	918.				little
NORTHUMBERLAND								
Coans	Thomas Fallin	drilled	260.					1.5
Hardings	Wharton Fisheries Co.	drilled		462.				.13
Lodge	Wharton Fisheries Co.	drilled	255.	220.				tr.
RICHMOND								
Warsaw	E. H. Garland	drilled	188.					1.
Warsaw	G. M. Sydnor	drilled	180.					
SOUTHAMPTON								
Boykins	Baptist Church	drilled	127.					tr.
Boykins	E. H. Grizzard	drilled	85.					tr.
Boykins	W. A. Powell	drilled	110.					tr.
Boykins	Town	drilled	90.					tr.
Courtland	R. T. Whitfield	drilled	165.	277.	20.	25.		.9
	Railroad	drilled		244.	23.	27.		.16
SURRY								
Homewood	W. F. Gray	drilled	250.					tr.
Homewood	W. F. Gray	drilled	315.	785.		37.		.1
WESTMORELAND								
Beales Wharf	Beales & Biddle	drilled	175.					
Kinsale	G. P. Bailey	drilled	238.					tr.
Kinsale	Dameron & Courtney	drilled	275.					
Lynch's Point	J. R. Dos Passos	drilled	90.					5.
Mount Holly	S. J. Hopkins	drilled	185.					
Sandy Point	J. R. DosPassos	drilled	250.					
WARWICK								
Curtis Point	Philip Lederhos	drilled	363.	910.		18.		.12
Mulberry Island	P. H. Wright	drilled	373.	1,158.		13.		tr.
Mulberry Island	P. H. Wright	drilled	373.					tr.

[a] Ammonium radicle (NH_4) 9.7; borate radicle (B_2O_7) trace.
[b] Sodium and potassium.

TABLE 8 *(Continued)—Analyses and field assays (F) of well water from Chesapeake formations.*

Aluminum (Al)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Phosphate radicle (PO_4)	Nitrate radicle (NO_3)	Bromine (Br)	Iodine (I)	Chlorine (Cl)	Total hardness as $CaCO_3$	Date	Analyst
		little					16.	450.	tr.					9.5	5.6	1906	S. Sanford (F)
		little					15.	360.	>30.					12.	8.	1906	S. Sanford (F)
								220.	tr.					6.	81.	1906	S. Sanford (F)
		74.	31.	50.			292.							78.		1905	Sparrows Point Boiler Compound Co.
		much					0.	240.	>30.					610.	140.	1907	S. Sanford (F)
		mod.					5.	200.	0.					19.	70.	1906	S. Sanford (F)
		some					0.	210.	>30.					420.	95.	1906	S. Sanford (F)
		some	some				some		little					427.		1901	C. B. Dudley
		some					0.	260.	0.					6.7	40.	1906	S. Sanford (F)
		7.2	1.8				24.	396.	.3					6.6		1907	R. B. Dole
									0.		0.			4.	42.		G. W. Lehmann
		mod.					0.	250.	>30.					5.	32.	1906	S. Sanford (F)
		little					0.	210.	0.					4.	34.	1906	S. Sanford (F)
		some					0.	170.	>30.					6.	62.	1907	S. Sanford (F)
		little					0.	170.	>30.					5.2	42.	1907	S. Sanford (F)
		little						150.	tr.					7.	21.(?)	1907	S. Sanford (F)
		little						150.	tr.					5.3	50.	1907	S. Sanford (F)
											0.			19.	16.	1909	N. S. Hill
											0.			18.	25.	1909	N. S. Hill
		0.					15.	425.	>30.					35.	7.3	1906	S. Sanford (F)
		6.8	2.2	295[b]			23.	468.	26.		.3			152.			R. B. Dole
		little					0.	185.	>30.					6.	12.	1906	S. Sanford (F)
		little					0.	210.	>30.					5.3	23.	1900	S. Sanford (F)
		little					0.	220.	>30.					5.3		1906	S. Sanford (F)
		some					0.	320.	much					7.	50.	1900	S. Sanford (F)
		some					0.	180.	>23.					5.	18.	1906	S. Sanford (F)
		little						250.	>30.					5.7	13.	1906	S. Sanford (F)
		7.2	1.2	350[b]			22.	448.	32.		tr.			244.		1902	R. B. Dole
		4.2	1.2	354.	15.	tr.		454.	44.					273.		1905	W. H. Taylor
							6.	400.	39.					250.	11.	1906	S. Sanford (F)

TABLE 9—*Analyses and field assays of well water from Pamunkey formations.*

Locality	Owner	Type of well	Depth (feet)	Total solids	Organic and volatile matter	Silica (SiO_2)	Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$)	Iron (Fe)
CAROLINE								
Port Royal	Town	drilled	235					
CHARLES CITY								
Roxbury	Thos. Walker	drilled	250					tr.
Westover	W. S. Ramsay	drilled	135					tr.
ESSEX								
Tappahannock	F. S. McDaniel	drilled	280					tr.
Tappahannock	R. T. Cauthorn	drilled		494.	48.			
Tappahannock	Donaldson & Schultz	drilled	256					
GLOUCESTER								
Sassafras	B. F. Weaver	drilled	336					2.
Achilles	Union Church	drilled	500					5.5
JAMES CITY								
Lee Hall	Duke & Smith	drilled	429					tr.
Lee Hall	Duke & Smith	drilled	395					tr.
Norge	Chesapeake & Ohio Ry.	drilled	419	718.	9.9	40.	6.	
KING GEORGE								
Mathias Point	C. H. Pemberton	drilled	286					tr.
Port Conway	R. V. Turner	drilled	232					tr.
Port Conway	J. H. Low	drilled	305					
Port Conway	R. V. Turner	drilled	250					
Port Conway	Dr. Jones	drilled	305					.3
Wilsmont Landing	Vulcan Fire Brick Co.	drilled	300(?)					
KING WILLIAM								
Aylett	J. B. Moore	drilled	190	303.		17.		.2
Elsing Green	Roger Gregory	drilled	300					tr.
West Point	West Point Waterworks	drilled	335					
KING AND QUEEN								
King and Queen	County	drilled	216					1.
Walkerton	Ivan Clark	drilled	235					tr.
LANCASTER								
Irvington	Carters Creek Fish Guano Co.	drilled	580					tr.
NEW KENT								
Boulevard	Wm. Webber	drilled	260	60.		23.		.06
Providence Forge	E. R. Richardson	drilled	215					tr.
Providence Forge	E. B. Towsend	drilled	250					tr.
NORTHUMBERLAND								
Harding	S. A. Whitaker	drilled		462.			.13	
RICHMOND								
Naylors Wharf	E. A. Waddington	drilled	320					
WESTMORELAND								
Colonial Beach	M. A. & E. S. Bentley	drilled	200					tr.
Colonial Beach	L. W. Jett		230					
Colonial Beach	Ice Works	drilled	235					
Erica	E. T. Barrett	drilled	335					tr.
Erica	Wm. Detrick	drilled	327					tr.
Wilkerson	W. S. Wilkerson	drilled	233					tr.
STAFFORD								
Brooke	Richmond, Fredericksburg and Potomac R. R. Co.	dug	20					tr.

TABLE 9 (*Continued*)—*Analyses and field assays of well water from Pamunkey formations.*

Aluminum (Al)	Manganese (Mn)	Calcium (Ca)	Strontium (Sr)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Nitrate radicle (NO_3)	Chlorine (Cl)	Total hardness as $CaCO_3$	Date	Analyst
......	......	little	....	......	......	......	......	0.	180.	>30.	....	6.	5.	1906	S. Sanford (F)
......	......	0.(?)	....	......	......	......	......	0.	195.	>30.	....	2.5	14.	1906	S. Sanford (F)
......	......	little	....	......	......	......	......	0.	405.	>30.	....	54.?	31.	1906	S. Sanford (F)
......	......	little	....	......	......	......	......	8.4	470.	>30.	....	7.5	11.	1906	S. Sanford (F)
......	......	....	....	......	......	......	......	......	......	34.	....	2.	25.	1904	G. H. Lehmann
......	......	....	....	......	......	......	......	0.	210.	>30.	....	8.6	56.	1906	S. Sanford (F)
......	......	little	....	......	......	......	......	>10.	645.	54.	....	220.	18.	1906	S. Sanford (F)
......	......	mod.	....	......	......	......	......	0.	800.	135.	....	1,500.	67.	1906	S. Sanford (F)
......	......	0.(?)	....	......	......	......	......	0.	440.	>30.	....	190.	7.3	1906	S. Sanford (F)
......	......	0.(?)	....	......	......	......	......	0.	470.	>30.	....	280.	12.	1906	S. Sanford (F)
......	......	11.	....	3.1	252.	......	......	180.	......	39.	....	176.	....	1910	Froehling & Robertson
......	......	0.(?)	....	......	......	......	......	0.	250.	>30.	....	12.5	7.	1906	S. Sanford (F)
......	......	little	....	......	......	......	......	0.	140.	>30.	....	5.	1.	1906	S. Sanford (F)
......	......	....	....	......	......	......	......	0.	190.	>30.	....	....	....	1906	S. Sanford (F)
......	......	little	....	......	......	......	......	0.	240.	>30.	....	>10.	....	1906	S. Sanford (F)
......	......	little	....	......	......	......	......	0.	190.	>30.	....	5.	2.	1906	S. Sanford (F)
......	......	little	....	......	......	......	......	0.	270.	>30.	....	5.	....	1906	S. Sanford (F)
......	......	3.2	....	.4	105.	8.8	......	22.	245.	18.	0.	1.0	....	1906	R. B. Dole
......	......	little	....	......	......	......	......	0.	360.	>30.	....	>10.	14.	1906	S. Sanford (F)
......	......	0.(?)	....	......	......	......	......	0.	480.	>30.	....	17.5	2.	1906	S. Sanford (F)
......	......	....	....	......	......	......	......	0.	220.	>30.	....	7.5	41.	1906	S. Sanford (F)
......	......	0.(?)	....	......	......	......	......	18.	280.	>30.	....	8.	7.3	1906	S. Sanford (F)
......	......	0.(?)	....	......	......	......	......	20.	500.	>30.	....	13.	1.	1906	S. Sanford (F)
.6	......	2.1	....	.4	9.2	......	......	0.	29.	1.6	4.4	6.5	....	1906	R. B. Dole
......	......	little	....	......	......	......	......	0.	200.	>30.	....	4.	24.	1906	S. Sanford (F)
......	......	little	....	......	......	......	......	10.?	300.	>30.	....	3.8	10.	1906	S. Sanford (F)
......	......	7.2	....	1.8	......	......	......	24.	396.	.3	....	5.5	....	1907	R. B. Dole
......	......	tr.	....	......	......	......	......	15.	390.	......	....	7.6	....	1906	S. Sanford (F)
......	......	little	....	......	......	......	......	8.	330.	>30.	....	11.	12.	1906	S. Sanford (F)
......	......	little	....	......	......	......	......	15.	270.	>30.	....	10.	16.	1906	S. Sanford (F)
......	......	5.	....	3.6	127.	......	......	0.	354.	20.	....	....	....	1906	M. G. Roberts
......	......	little	....	......	......	......	......	0.	340.	>30.	....	>10.	18.	1906	S. Sanford (F)
......	......	....	....	......	......	......	......	20.	395.	>30.	....	5.	11.	1906	S. Sanford (F)
......	......	little	....	......	......	......	......	18.	380.	>30.	....	9.	11.	1906	S. Sanford (F)
......	......	little	....	......	......	......	......	0.	25.	>30.	....	9.	5.6	1906	S. Sanford (F)

TABLE 10—*Analyses and field assays (F) of well water from Upper Cretaceous formations.*

Locality	Owner	Type of well	Depth (feet)	Total solids	Organic and volatile matter	Silica (SiO$_2$)
ELIZABETH CITY						
Fort Monroe	Hotel Chamberlain	drilled	945.	9,131.	47.	20.
Fort Monroe	Hotel Chamberlain	drilled	945.	9,248.	......	14.
Fort Monroe	Hotel Chamberlain	drilled	945.	8,846.	......	......
Fort Monroe	Hotel Chamberlain	drilled	945.	....	......	......
GLOUCESTER						
Achilles	B. A. Rowe	drilled	600.	....	......	......
Gloucester Point	County and Chesapeake Steamship Co.	drilled	694.	....	......	......
Roanes	A. W. Withers	drilled	716½	3,417.	......	20.
Severn	J. M. Shakelford	drilled	610.	5,008.	......	39.
KING WILLIAM						
Manquin	E. B. Chapman	drilled	237.	232.	......	23.
Manquin	Miss Cora Skidmore	drilled	270.	....	......	tr.
LANCASTER						
Ocran	....	drilled	660.	616.	......	56.
MIDDLESEX						
Urbanna	J. W. Hurley	drilled	650.	....	......	......
NANSEMOND						
Suffolk	Norfolk & Portsmouth Traction Co.	drilled	803.(?)	596.	20.	......
NORFOLK						
Lamberts Point	N. & W. R. R.	drilled	616.	1,098.	......	19.
Lamberts Point	N. & W. R. R.	drilled	616.	....	......	16.
Lamberts Point	N. & W. R. R.	drilled	616.	....	......	11.
Lamberts Point	N. & W. R. R.	drilled	616.	....	......	......
Lamberts Point	N. & W. R. R.	drilled	616.	1,067.	......	8.85
Lamberts Point	N. & W. R. R.	drilled	616.	86.	......	2.4
Lamberts Point	N. & W. R. R.	drilled	616.	1,128.	......	6.
NORTHUMBERLAND						
Fairport	....	....	690?	214.	80.	......

[a] Sodium and potassium.

TABLE 10—*(Continued)—Analyses and field assays (F) of well water from Upper Cretaceous formations.*

Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$)	Iron (Fe)	Aluminum (Al)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Nitrate radicle (NO_3)	Chlorine (Cl)	Total hardness as $CaCO_3$	Date	Analyst
16.	......	....	....	88.	71.	3,339.	....	....	328.	....	251.	tr.	4,929.	......	1906	Penniman & Brown
......	16.	23.	....	97.	44.	3,268.	87.	tr.	....	433.	265.	......	4,978.	......	1906	W. H. Taylor
......	......	....	....	......	......	....	....	....	....	....	....	......	....	133.	1896	Booth, Garrett & Blair
......	6.	....	....	mod.	......	....	....	....	5.	740.	180.	......	4,530.	70.	1906	S. Sanford (F)
......	2.5	....	....	much	......	....	....	....	5.(?)	840.	160.	......	1,400.	57.	1906	S. Sanford (F)
......	1.	....	....	little	......	....	....	....	6.	730.	38.	......	410.	21.	1906	S. Sanford (F)
......	1.	....	....	23.	14.	1,188.[a]	....	....	21.	544.	155.	tr.	1,630.	......	1906	R. B. Dole
......	4.9	....	....	46.	26.	1,896.[a]	....	....	0.	628.	216.	.7	2,500.	......	1906	R. B. Dole
......	1.	....	....	1.4	.2	74.	5.	....	6.7	188.	18.	0.	1.1	......	1906	R. B. Dole
......	tr.	....	....	little	......	....	....	....	0.	210.	>30.	......	>10.	2.	1906	S. Sanford (F)
......	tr.	....	....	little	little	much	s'me	e...	much	....	some	......	some	......	1907	G. H. Seyms
......	tr.	....	....	0.	......	....	....	....	14.	315.	>30.	......	9.	0.	1906	S. Sanford (F)
......	tr.	....	....	2.9	1.7	<214.	....	....	<280.	....	9.8	0.	23.	18.	1904	First Scientific Station for the Art of Brewing
0.91	......	....	....	5.	1.7	415.	21.	....	245.	....	43.	......	351.	......	1891	Shepard Laboratory
2.3	......	....	....	5.2	2.4	459.	....	....	....	601.	43.	......	291.	......	1906	N. & W. Railway
2.6	......	....	....	4.8	2.7	434.	....	....	....	617.	43.	......	298.	......	1907	Dearborn Laboratories
......	.5	....	....	little	......	....	....	....	9.	560.	41.	......	290.	......	1906	S. Sanford (F)
......	1.37	....	....	3.9	2.2	340.	11.	....	370.	....	45.	......	300.	......	....	N. & W. Railway
1.2	......	....	....	6.3	4.7	16.5	....	....	10.	....	20.	......	23.	......	1909	N. & W. Railway
1.9	......	....	....	5.1	3.8	437.	....	....	312.	....	45.	......	290.	......	1909	N. & W. Railway
......	......	....	....	......	......	....	....	....	....	....	0.	0.	6.	67.	....	G. H. Lehmann

TABLE 11—*Analyses and field assays (F) of well water from Potomac formations.*

Locality	Owner	Type of well	Depth (feet)	Total solids	Organic and volatile matter	Silica (SiO_2)
ALEXANDRIA						
Alexandria	New Washington Brick Co.			86.		[illegible]
Alexandria	Belle Pre Bottle Co.	drilled	155.	110.		[illegible]
Alexandria	Mutual Ice Co.	drilled	401.	176.		21.
Alexandria	Robert Portner Brewing Co.	drilled	431.	170.	14.	
Alexandria	Robert Portner Brewing Co.	drilled	400?	205.		27.
Alexandria	Robert Portner Brewing Co.	drilled	431.			
FAIRFAX						
Fort Hunt	United States	drilled	215.	342.		
GLOUCESTER						
Roanes	Joseph Bryan		850.(?)			
KING GEORGE						
Sealston	John Curtis	drilled	250.			
KING WILLIAM						
Palls	J. H. Montague	drilled	399.			
MATHEWS						
Mathews C. H.	County	drilled	817.			
PRINCE GEORGE						
City Point	Misses Eppes	drilled	111.	179.		[illegible]
PRINCESS ANNE						
Waterway	Norfolk City Waterworks	drilled	1,100.(?)			
SOUTHAMPTON						
Sebrell	Tidewater Railway	drilled	344.	295.	9.9	[illegible]
SPOTTSYLVANIA						
Fredericksburg	E. D. Cole	drilled	120.	43.	4.3	12.

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[a] Sodium and potassium.
[b] Oxide and carbonate of iron 6.8

TABLE 11 *(Continued)—Analyses and field assays (F) of well water from Potomac formations.*

Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$)	Iron (Fe)	Aluminum (Al)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Nitrate radicle (NO_3)	Chlorine (Cl)	Total hardness as $CaCO_3$	Date	Analyst
......	1.4	....	....	4.1	2.6	10.	....	....	0.	30.	11.	0.	6.9	......	1910	Chase Palmer
[a]....	4.6	....	....	6.5	3.9	12.	....	....	0.	51.	6.4	1.	13.	......	1910	Chase Palmer
......	......	....	....	tr.	1.4	49.	....	....	....	39.	36.	......	32.	......	1899	J. D. Hird
4.	......	....	....	7.1	.0	....	....	....	....	....	17.	0.	19.5	200.	1903	First Scientific Station for the Art of Brewing
......	1.	....	....	8.6	19.	32.	....	....	tr.	105.	3.	tr.	47.	......	1910	Chase Palmer
..	tr.	....	....	......	......	....	....	....	....	130.	>30.	......	44.	......	....	S. Sanford (F)
......	......	....	....	......	......	....	....	....	....	....	......	......	5.4	......	....	W. Mew
......	2.5	....	....	mod.	......	....	....	....	11.	660.	100.	......	1,090.	33.	1906	S. Sanford (F)
......	......	....	....	mod.	......	....	....	....	0.	120.	tr.	......	....	......	1906	S. Sanford (F)
......	tr.	....	....	tr.	......	....	....	....	0.	175.	>30.	......	5.	7.5	....	S. Sanford (F)
......	3.	....	....	much	......	....	....	....	0.	673.	tr.	......	167.	......	1906	R. B. Dole (F)
.....	.4	....	....	52.	3.2	16.[a]	....	....	0.	155.	5.3	6.	16.	......	1906	R. B. Dole (F)
......	tr.	....	....	little	......	....	....	....	5.	610.	110.	......	1,030.	7.5	1906	S. Sanford (F)
2.1	......	....	....	.79	.26	82.	....	....	84.	....	25.	......	10.6	......	1901	....
(b)	......	....	....	.5	2.9	3.8	....	....	10.	....	3.5	......	....	......	....	J. N. Barney

INDEX

- Accomac County, 117-133.
    - General description. 117.
    - Local supplies, 119.
        - Chincoteague, 121.
        - Conclusions, 133.
        - Franklin City and Greenbackville. 120.
        - New Church, 119.
        - Wells on islands in Chesapeake Bay. 131.
        - Wells on the bay side at Saxis. Belinda. Marsh Market, and Grotons, 122.
        - Wells on the bay side farther south. 123.
        - Wells on the ocean side south of Chincoteague Bay, 131.
    - Underground waters, 117.
        - Distribution and quality. 117.
        - Springs, 118.
        - Wells. 118.
- Acknowledgments, 1.
- Albemarle Paper Co., 85.
- Alexandria. 137.
- Alexandria County, 133-141.
    - General description, 133.
    - Local supplies, 137.
        - Alexandria, 137.
        - Conclusions, 141.
        - Other localities, 139.
    - Underground waters, 134.
        - Erup Mineral Spring, 135.
        - Hume, 134.
        - Occurrence and quality, 134.
        - Public supplies, 137.
        - Springs, 134.
- Analyses of waters from wells in crystalline rocks near Richmond, 94.
- Aquia formation, 18.
- Areal extent of pollution, 43.
- Artesian conditions, 51.
- Artesian sands, 55.
- Artesian springs, 46.
- Artesian supplies, conservation of, 59.
- Artesian waters, 51.
    - quality of, 54.
- Artesian wells. fluctuation of level in, 54.
- Back River. 102.
- Blackwater River. flowing wells along, 195.
- Bored wells, 64.
- Bowling Green. 142.
- Calvert formation, 20.
- Caroline County. 141-145.
    - General description. 141.
    - Local supplies, 142.
        - Bowling Green, 142.
        - Conclusions. 144.
        - Other localities, 143.
    - Underground waters. 142.
        - Springs. 142.
        - Wells, 142.
- Causes. losses of head. etc.. 69.
- Causes of mineralization, 114.
- Changes in quality of the water. 97.
- Charles City County. 145-149.
    - General description. 145.
    - Local supplies, 146.
        - Conclusions. 149.
    - Underground waters. 145.
        - Occurrence and character. 145.
        - Springs. 146.
        - Wells. 146.
- Chemical composition of ground water. 41.
- Chesapeake group, 19.
    - Divisions, 20.
        - Calvert formation, 20.
        - Choptank formation, 20.
        - St. Mary's formation. 20.
        - Yorktown formation, 20.
    - Extent and character, 19.
    - Water supplies, 21.
- Chesapeake sands. 57.
- Chesterfield Apartments, 87.
- Chesterfield County. 149-158.
    - General description, 149.
    - Local supplies, 157.
        - Conclusions, 158.
    - Underground waters, 149.
        - Occurrence and character. 149.
        - Springs, 150.
        - Wells, 157.
- Choptank formation, 20.
- Circulation of ground water, 39.
- Cisterns. 60.
- City and town supplies, notes on. 76.
- Climate. Coastal Plain, 7.
- Coastal Plain, 7-13.
    - Climate. 7.
    - Crystalline rocks, 12.
        - Bed rock topography, 12.
        - Character and extent, 12.
    - Geographic position, 7.
    - Geologic relations of Coastal Plain deposits, 11.
        - General description, 11.

    Thickness of deposits, 11.
  Topography, 10.
    General description, 10.
    Terraces, 10.
    Topographic types, 10.
  Water supplies, 13.
Coastal Plain an artesian slope, 52.
Collecting tunnels and drains, 61.
  General statement, 61.
  Mount Vernon, 62.
Columbia beds, undifferentiated, 26.
Columbia group, 23.
  Character and extent, 23.
  Divisions, 23.
    Origin, 25.
    Sunderland formation, 25.
    Talbot formation, 25.
    Wicomico formation, 25.
  Water supplies, 26.
Columbia sands, 58.
Comparison of records, deep wells, 113.
Composition of deep water, 51.
Conclusions, underground water supply by counties (*see under individual counties*).
Conservation of artesian supplies, 59.
Controlling factors in soil absorption, 31.
Cretaceous, 14.
      Lower, 14.
      Upper, 16.
Crystalline rocks, 12.
      deep wells in, 83.
Deep circulation, ground water, 48.
Deep water, freshening of, 114.
Deep waters of the Norfolk-Newport News area, 97.
  General statement, 97.
  Limits of area, 98.
Deep wells in crystalline rocks, 83.
  Analyses of waters from wells in crystalline rocks near Richmond, 94.
    Changes in quality of the water, 97.
  Emporia, 93.
  General statement, 83.
  Probability of finding water by deep wells, 94.
  Wells in the northwestern part of Richmond and outlying districts to the northwest, 90.
  Wells near Richmond, 85.
    General conditions, 85.
  Wells near river front, 85.
    Albemarle Paper Co., 85.
    Other wells, 86.
    Richmond Paper Co., 85.
  Wells near the center of the city, 86.
    Chesterfield Apartments, 87.
    Hotel Jefferson, 86.
    Murphy's Hotel, 88.
    Richmond Hotel, 89.
  Wells south of Richmond, 92.
Deep wells north of James River, 99.
  Back River, 102.
  Fort Monroe, 99.
  Hotel Chamberlain, 104.
  Newport News, 101.
Deep wells north of Suffolk, 230.
Deep wells, probability of finding water by, 94.
Deep wells south of James River, 106.
  General statement, 106.
  Lambert Point, 107.
  Masons Creek, 107.
  Money Point, 107.
  Moore's Bridges, 109.
  Virginia Beach, 107.
Definition of artesian waters, 51.
      ground water, 37.
Dinwiddie County, 158-159.
    General description, 158.
    Geology, 158.
  Local supplies, 159.
    Conclusions, 159.
  Underground waters, 158.
    Occurrence and character, 158.
    Springs, 159.
    Wells, 159.
Distribution and quality of underground waters (*see under individual counties*).
Distribution, origin, occurrence, and, of underground waters, 31.
Divisions of Chesapeake group, 20.
      Columbia group, 23.
      Pamunkey group, 17.
      Potomac group, 15.
Drilled wells, 65.
Driven wells, 64.
Dug wells, 63.
Elizabeth City County, 159-163.
    General description, 159.
    Geology, 160.
  Local supplies, 160.
    Conclusions, 163.
  Underground waters, 160.
    Distribution and quality, 160.
    Springs, 160.
    Wells, 160.
Emergence of ground water, 44.
Emporia, 93.
Eocene, 17.
Erup Mineral Spring, 135.
Essex County, 163-169.
    General description, 163.
  Local supplies, 165.

    Conclusions, 169.
  Underground waters, 163.
    Character and extent, 163.
    Springs, 164.
    Wells, 165.
Evaporation, 31.
Fairfax County, 169-175.
    General description, 169.
  Local supplies, 171.
    Conclusions, 175.
  Underground waters, 170.
    Occurrence and character, 170.
    Springs, 171.
    Wells, 171.
Faults in maintenance, 70.
  Abuse, 70.
  Neglect, 70.
Faults in sinking, 70.
Flowing well areas, 58.
Flowing wells along Blackwater River, 195.
    James River, 194.
    rams at, 73.
Fluctuation of level in artesian wells, 54.
    water table, 37.
Fort Monroe, 99.
Freshening of deep water, 114.
Function of ground water, 48.
Geographic position, Coastal Plain, 7.
Geologic formations and their water supplies, summary of, 28.
Geologic relations, Coastal Plain deposits, 11.
Geology (*see under individual counties*).
Gloucester County, 175-181.
    General description, 175.
    Geology, 175.
  Local supplies, 177.
    Conclusions, 180.
  Underground waters, 175.
    Distribution and quality, 175.
    Springs, 176.
    Wells, 177.
Greenesville County, 181-182.
    General description, 181.
    Geology, 181.
  Local supplies, 181.
  Underground waters, 181.
    Distribution and quality, 181.
Ground water, 37-59.
  Areal extent of pollution, 43.
  Artesian sands, 55.
    Chesapeake sands, 57.
    Columbia sands, 58.
    Conservation of artesian supplies, 59.
    Flowing well areas, 58.
    Number, 55.
    Pamunkey sands, 56.
    Potomac sands, 56.
  Artesian waters, 51.
    Artesian conditions, 51.
    Coastal Plain an artesian slope, 52.
    Definition of, 51.
    Initial head, 53.
    Loss of head, 53.
    Ponded water, 53.
    Source of artesian water, 52.
  Chemical composition of, 41.
  Circulation of, 39.
  Deep and artesian waters, 48.
    Composition of deep water, 51.
    Deep circulation, 48.
    Function of ground water, 48.
    Temperatures of deep water, 49.
  Definition of, 37.
  Emergence of, 44.
    Artesian springs, 46.
    Normal springs, 46.
    Perched springs, 46.
    Seeps, 44.
    Springs, 44.
  Fluctuation of level in artesian wells, 54.
  Fluctuations of water table, 37.
  Ground water temperature, 41.
  Normal chlorine of, 42.
  Perched ground water, 38.
  Permanence of flow, 47.
  Pollution of, 43.
  Purity of supply, 47.
    Pollution of spring sources, 47.
    Quality of spring waters, 48.
  Quality of artesian waters, 54.
  Rate of movement of, 40.
  Sources of spring waters, 46.
  Underground lakes and rivers, 41.
  Water table, 37.
Ground water temperature, 41.
Hanover County 82-187.
    General description, 182.
    Geology, 182.
  Local supplies, 184.
    Conclusions, 187.
  Underground waters, 183.
    Distribution and character, 183.
    Springs, 183.
Henrico County, 187-192.
    General description, 187.
    Geology, 187.
  Local supplies, 190.
    Conclusions, 192.
  Underground waters, 188.
    Description and character, 188.
    Springs, 188.

    Wells, 189.
Hotel Chamberlain, 104.
Hotel Jefferson, 86.
Hume, 134.
Improvement of springs, 61.
Initial head, 53.
Interference, 71.
Introduction, 1.
  Acknowledgments, 1.
  Literature, 2.
  Results of investigation, 3.
  Scope of report, 1.
Isle of Wight County, 192-196.
    General description, 192.
    Geology, 193.
  Local supplies, 194.
    Conclusions, 196.
    Flowing wells along Blackwater River, 195.
    Flowing wells along James River, 194.
  Underground waters, 193.
    Distribution and quality, 193.
    Springs, 193.
    Wells, 193.
James City County, 196-200.
    General description, 196.
    Geology, 196.
  Local supplies, 197.
    Conclusions, 200.
  Underground waters, 197.
    Distribution and quality, 197.
    Springs, 197.
    Wells, 197.
James River, deep wells north of, 99.
  deep wells south of, 106.
  flowing wells along, 194.
King and Queen County, 200-204.
    General description, 200.
    Geology, 201.
  Local supplies, 202.
    Conclusions, 204.
  Underground waters, 201.
    Distribution and quality, 201.
    Springs, 201.
    Wells, 202.
King George County, 204-208.
    General description, 204.
    Geology, 204.
  Local supplies, 205.
    Conclusions, 207.
    Potomac River, 206.
    Rappahannock River, 205.
  Underground waters, 205.
    Distribution and quality, 205.
    Springs, 205.
    Wells, 205.
King William County, 208-213.
    General description, 208.
    Geology, 208.
    Topography, 208.
  Local supplies, 209.
    Conclusions, 213.
  Underground waters, 208.
    Distribution and quality, 208.
    Springs, 209.
    Wells, 209.
Lafayette formation, 21.
    Extent and character, 21.
    Origin, 22.
  Water supplies, 22.
Lambert Point, 107.
Lancaster County, 213-219.
    General description, 213.
    Geology, 214.
  Local supplies, 215.
    Conclusions, 219.
  Underground waters, 214.
    Distribution and quality, 214.
    Springs, 214.
    Wells, 215.
Limits of area (Norfolk-Newport News), 98.
Literature, 2.
Local supplies, underground water (*see under individual counties*).
Loss of head, 53.
Losses of head or yield in flowing wells, 69.
  Causes of, 69.
Lower Cretaceous, 14.
Magnetic wells, 68.
Masons Creek, 107.
Mathews County, 219-222.
    General description, 219.
    Geology, 220.
  Local supplies, 221.
    Conclusions, 222.
  Underground waters, 220.
    Extent and character, 220.
    Springs, 220.
    Wells, 221.
Middlesex County, 222-227.
    General description, 222.
    Geology, 223.
  Local supplies, 224.
    Conclusions, 227.
  Underground waters, 223.
    Distribution and quality, 223.
    Springs, 223.
    Wells, 224.
Mineral waters, 82.
  Value of, 83.
Mineralization, causes of, 114.
Miocene, 19.
Money Point, 107.

Moore's Bridges, 109.
Mount Vernon collecting tunnels. 62.
Municipal water supplies, 75.
  Notes on city and town supply, 76.
  Source of, 75.
  Stability of surface and underground waters, etc., 76.
  Surface water, 75.
  Underground water, 76.
Murphy's Hotel, 88.
Nanjemoy formation, 18.
Nansemond County, 227-231.
    General description. 227.
    Geology, 228.
  Local supplies, 229.
    Conclusions, 231.
    Deep wells north of Suffolk. 230.
  Underground waters, 228.
    Extent and distribution. 228.
    Springs, 228.
    Wells, 228.
New Kent County, 231-235.
    General description, 231.
    Geology, 232.
  Local supplies, 233.
    Conclusions, 235.
  Underground waters, 232.
    Distribution and quality, 232.
    Springs, 232.
    Wells, 233.
Newport News, 101.
Norfolk County, 235-243.
    General description, 235.
    Geology, 235.
  Local supplies. 237.
    Conclusions, 243.
  Underground waters. 236.
    Distribution and quality. 236.
    Springs, 236.
    Wells, 237.
Normal chlorine, 42.
Normal springs, 46.
Northampton County. 243-248.
    General description. 243.
    Geology, 243.
  Local supplies, 244.
    Conclusions, 248.
  Underground waters. 243.
    Distribution and quality. 243.
    Springs, 244.
    Wells, 244.
Northumberland County. 249-252.
    General description. 249.
    Geology, 249.
  Local supplies. 250.
    Conclusions. 252.
  Underground waters, 249.
    Distribution and quality, 249.
    Springs, 249.
    Wells, 249.
Notes on city and town supplies. 76.
Number, artesian sands, 55.
Occurrence, and distribution, origin, of underground waters. 31.
Origin, occurrence, and distribution of underground waters, 31.
Other localities, Alexandria County, 139.
  Caroline County, 143.
Other wells, 86.
Pamunkey group, 17.
  Divisions, 18.
    Aquia formation, 18.
    Nanjemoy formation, 18.
  Extent and character, 17.
  Water supplies, 19.
Pamunkey sands, 56.
Patapsco formation, 15.
Patuxent formation, 15.
Perched ground water, 38.
Perched springs, 46.
Permanence of flow, ground water, 47.
Piedmont Plateau, 5.
Pleistocene, 23.
Pliocene (?), 21.
Pollution of ground water, 43.
Pollution of spring sources, 47.
Ponded water, 53.
Potomac group, 14.
  Divisions, 15.
    Patapsco formation, 15.
    Patuxent formation, 15.
  Extent and character, 14.
  Origin, 15.
  Water supplies, 16.
Potomac River, King George County. 206.
Potomac sands. 56.
Prince George County, 252-256.
    General description, 252.
    Geology, 252.
  Local supplies, 254.
    Conclusions, 255.
  Underground waters, 253.
    Distribution and quality, 253.
    Springs, 253.
    Wells. 254.
Prince William County, 260-263.
    General description, 260.
    Geology, 260.
  Local supplies, 261.
  Underground waters, 261.
Princess Anne County, 256-260.
    General description, 256.
    Geology, 256.
  Local supplies, 257.
    Conclusions, 259.

  Underground waters, 256.
    Distribution and quality, 256.
    Springs, 257.
    Wells, 257.
Probability of finding water by deep wells, 94.
Public health as related to underground water supply, 75.
Public supplies, Alexandria County, 137.
Purity of supply, ground water, 47.
Quality of artesian waters, 54.
Quality of spring waters, 48.
Quality of the water, changes in, 97.
Rams at flowing wells, 73.
      use of, 61.
Rappahannock River, King George County, 205.
Rate of movement of ground water, 40.
Records, deep wells, comparison of, 113.
Recovery of water, 60-116.
  Causes of mineralization, 114.
  Cisterns, 60.
  Collecting tunnels and drains, 61.
    General statement, 61.
    Mount Vernon collecting tunnels, 62.
  Comparison of records, 113.
  Deep waters of the Norfolk-Newport News area, 97.
    General statement, 97.
    Limits of area, 98.
  Deep wells in crystalline rocks, 83.
    Analyses of waters from wells in crystalline rocks near Richmond, 94.
      Changes in quality of the water, 97.
    Emporia, 93.
    General statement, 83.
    Probability of finding water by deep wells, 94.
    Wells in the northwestern part of Richmond and in outlying districts to the northwest, 90.
    Wells near Richmond, 85.
      General conditions, 85.
    Wells near river front, 85.
      Albemarle Paper Co., 85.
      Other wells, 86.
      Richmond Paper Co., 85.
    Wells near the center of the city, 86.
      Chesterfield Apartments, 87.
      Hotel Jefferson, 86.
      Murphy's Hotel, 88.
      Richmond Hotel, 89.
    Wells south of Richmond, 92.
  Deep wells north of James River, 99.
    Back River, 102.
    Fort Monroe, 99.
    Hotel Chamberlain, 104.
    Newport News, 101.
  Deep wells south of James River, 106.
    General statement, 106.
    Lambert Point, 107.
    Masons Creek, 107.
    Money Point, 107.
    Moore's Bridges, 109.
    Virginia Beach, 107.
  Faults in maintenance, 70.
    Abuse, 70.
    Neglect, 70.
  Faults in sinking, 70.
  Freshening of deep water, 114.
  Interference, 71.
  Losses of head or yield in flowing wells, 69.
    Causes, 69.
  Magnetic wells, 68.
  Mineral waters, 82.
    Value of, 83.
  Municipal water supplies, 75.
    Notes on city and town supplies, 76.
    Source of supply, 75.
    Stability of surface and underground waters for municipal needs, 76.
    Surface water, 75.
    Underground water, 76.
  Public health as related to underground water supply, 75.
  Sanitary protection of wells, 73.
  Springs and seeps, 60.
    Improvement of springs, 61.
    Use of rams, 61.
  Summary, 116.
  Utilization of supply, 72.
    Rams at flowing wells, 73.
  Wells, 63.
    bored, 64.
    drilled, 65.
    driven, 64.
    dug, 63.
  Yield of wells, 68.
Results of investigation, 3.
Richmond, analyses of waters from wells in crystalline rocks near, 94.
Richmond County, 263-267.
    General description, 263.
    Geology, 263.
  Local supplies, 264.
    Conclusions, 266.
  Underground waters, 263.
    Distribution and quality, 263.
    Springs, 263.
    Wells, 263.
Richmond Hotel, 89.
Richmond Paper Co., 85.

Richmond, wells in the northwestern part and outlying districts, 90.
      wells near, 85.
      wells south of, 92.
Run-off, 31.
Sanitary protection of wells, 73.
Scope of report, 1.
Sedimentary deposits, 14.
Seeps, 44.
Soil solutions, 36.
Soils, 32.
Soils and soil solutions, 32.
Soils, storage capacity of, 32.
Source of artesian water, 52.
Source of supply, 75.
Sources of spring waters, 46.
Southampton County, 267-272.
    General description, 267.
    Geology, 267.
  Local supplies, 268.
    Conclusions, 272.
  Underground waters, 268.
    Distribution and quality, 268.
    Springs, 268.
    Wells, 268.
Spottsylvania County, 272-275.
    General description, 272.
  Underground waters, 273.
    Conclusions, 274.
    Distribution and quality, 273.
    Springs, 273.
    Wells, 274.
Spring waters, quality of, 48.
      sources of, 46.
Springs (*see under individual counties*).
Springs, 44.
      artesian, 46.
      improvement of, 61.
      normal, 46.
      perched, 46.
Springs and seeps, 60.
  Improvement of, 61.
  Use of rams at, 61.
St. Mary's formation, 20.
Stability of surface and underground waters, etc., 76.
Stafford County, 275.
    General description, 275.
    Geology, 275.
  Underground waters, 275.
Storage capacity of soils, 32.
Suffolk, deep wells north of, 230.
Summary, deep water, 116.
Sunderland formation, 25.
Surface water, 75.
Surry County, 276-281.
    General description, 275.
    Geology, 276.
  Local supplies, 278.
    Conclusions, 280.
  Underground waters, 276.
    Distribution and quality, 276.
    Springs, 277.
    Wells, 278.
Sussex County, 281-283.
    General description, 281.
    Geology, 281.
  Local supplies, 282.
  Underground waters, 281.
    Distribution and quality, 281.
    Springs, 282.
    Wells, 282.
Tables of spring data, 334-337.
      well data, 298-333, 338-353.
Tabulated well data, 295.
Talbot formation, 25.
Temperature of deep water, 49.
Tertiary, 17.
Topographic and geologic provinces of Virginia, 5-13.
  Coastal Plain, 7.
    Climate, 7.
    Crystalline rocks, 12.
    Geographic position, 7.
    Geological relation of Coastal Plain deposits, 11.
    Topography, 10.
    Water supplies, 13.
  Piedmont Plateau, 5.
Topography, Coastal Plain, 10.
Town supplies, notes on city and, 76.
Underground lakes and rivers, 41.
Underground water, 76.
Underground water supplies by counties, 117-296.
  Accomac, 117-133.
  Alexandria, 133-141.
  Caroline, 141-145.
  Charles City, 145-149.
  Chesterfield, 149-158.
  Dinwiddie, 158-159.
  Elizabeth City, 159-163.
  Essex, 163-169.
  Fairfax, 169-175.
  Gloucester, 175-181.
  Greenesville, 181-182.
  Hanover, 182-187.
  Henrico, 187-192.
  Isle of Wight, 192-196.
  James City, 196-200.
  King and Queen, 200-204.
  King George, 204-208.
  King William, 208-213.
  Lancaster, 213-219.
  Mathews, 219-222.
  Middlesex, 222-227.

  Nansemond, 227-231.
  New Kent, 231-235.
  Norfolk, 235-243.
  Northampton, 243-248.
  Northumberland, 249-252.
  Prince George, 252-256.
  Prince William, 260-263.
  Princess Anne, 256-260.
  Richmond, 263-267.
  Southampton, 267-272.
  Spottsylvania, 272-275.
  Stafford, 275.
  Surry, 276-281.
  Sussex, 281-283.
  Warwick, 284-286.
  Westmoreland, 286-292.
  York, 292-295.
Underground water supply, public health as related to, 75.
Underground waters (*see under individual counties*).
Underground waters, 31-36.
  Origin, occurrence, and distribution, 31.
    Controlling factors in soil absorption, 31.
    Evaporation, 31.
    General statement, 31.
    Run-off, 31.
    Storage capacity of soils, 32.
  Soils and soil solutions, 32.
    Soil solutions, 36.
    Soils, 32.
Undifferentiated Columbia beds, 26.
Upper Cretaceous, 16.
Use of rams, 61.
Utilization of supply, 72.
  Rams at flowing wells, 73.
Value of mineral waters, 83.
Virginia Beach, 107.
Warwick County, 284-286.
    General description, 284.
    Geology, 284.
  Local supplies, 285.
    Conclusions, 286.
  Underground waters, 284.
    Distribution and quality, 284.
    Springs, 284.
    Wells, 285.
Water supplies, Chesapeake group, 21.
      Coastal Plain, 13.
      Columbia group, 26.
      Lafayette formation, 22.
      Pamunkey group, 19.
      Potomac group, 16.
      undifferentiated, Columbia, beds, 27.
Water table, 37.
Well data, tabulated, 295.
Wells, 63.
  bored, 63.
  drilled, 64.
  driven, 64.
  dug, 63.
  magnetic, 68.
  yield of, 68.
Wells (*see under individual counties*).
Wells in the northwestern part of Richmond and outlying districts, 90.
Wells near Richmond, 85.
Wells near river front, 85.
  Albemarle Paper Co., 85.
  Other wells, 86.
  Richmond Paper Co., 85.
Wells near the center of the city, 86.
  Chesterfield Apartments, 87.
  Hotel Jefferson, 86.
  Murphy's Hotel, 88.
  Richmond Hotel, 89.
Wells, sanitary protection of, 73.
Wells south of Richmond, 92.
Westmoreland County, 286-292.
    General description, 286.
    Geology, 287.
  Local supplies, 288.
    Conclusions, 292.
  Underground waters, 287.
    Distribution and quality, 287.
    Springs, 288.
    Wells, 288.
Wicomico formation, 25.
Yield of wells, 68.
York County, 292-295.
    General description, 292.
    Geology, 292.
  Local supplies, 293.
    Conclusions, 294.
  Underground waters, 293.
    Distribution and quality, 293.
    Springs, 293.
    Wells, 293.
Yorktown formation, 20.

VIRGINIA GEOLOGICAL SURVEY
UNIVERSITY OF VIRGINIA
THOMAS LEONARD WATSON, PH. D.
DIRECTOR

Bulletin No. VI

Biennial Report

ON THE

Mineral Production of Virginia

During the Calendar Years

1909 and 1910

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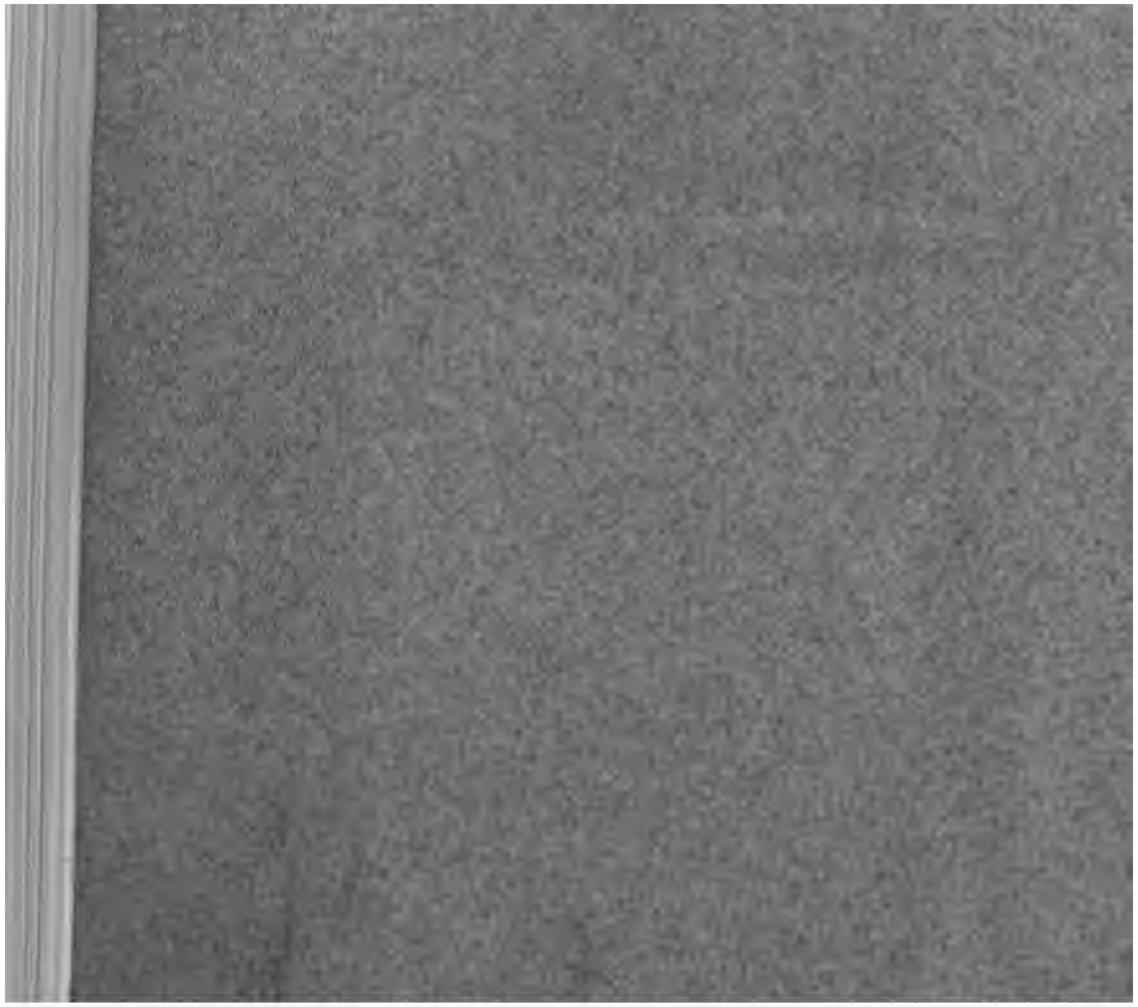
THOMAS LEONARD WATSON



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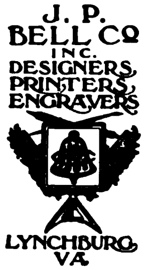
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THOMAS LEONARD WATSON,
Director of the Survey.

CONTENTS

PAGE
- Illustration v
- Introduction 1
- Preliminary Generalities 7
  - Geographic position of Virginia 7
  - Surface features of the State 7
    - The Coastal Plain province 9
    - The Piedmont Plateau province 10
    - The Appalachian Mountains province 11
  - Effects of weathering and erosion 12
  - Diversity of resources 12
- Iron Ores and Pig Iron 13
- Manganese Ores 23
- Gold and Silver 27
- Copper 31
- Lead and Zinc 35
- Tin 37
- Nickel and Cobalt 38
- Coal 38
- Coke 46
- Clay and Clay Products 50
  - Brick clays 53
  - Fire clays 55
  - Pottery clays 56
  - Kaolin 56
- Lime and Cement 59
  - Lime 60
  - Cement 63
- Sand and Gravel 67
- Sand-Lime Brick 70
- Stone 71
  - Granite 72
  - Marble 77
  - Limestone 77
  - Sandstone 82
  - Slate 85
  - Crushed stone 88
    - Road materials
    - Ballast and concrete 89
  - Furnace flux 90

PAGE
ABRASIVE MATERIALS 91
  Corundum and emery 91
    Corundum 91
    Emery 91
  Millstones (buhrstones) 91
SILICA 93
  Quartz 93
  Chert 93
  Diatomaceous earth 93
MICA 94
FELDSPAR 96
ASBESTOS 97
TALC AND SOAPSTONE 98
BARYTES 102
GYPSUM 105
SALT 106
MINERAL PAINTS 107
MARL 107
PYRITE AND PYRRHOTITE 108
ARSENIC 111
PHOSPHATE 112
GRAPHITE 113
RUTILE (TITANIUM) 113
MINERAL WATERS 115
PRECIOUS STONES 119
INDEX 121

ILLUSTRATION

FIGURE PAGE
1. Sketch map of Virginia showing physiographic provinces 8

LETTER OF TRANSMITTAL

VIRGINIA GEOLOGICAL SURVEY,
UNIVERSITY OF VIRGINIA,
CHARLOTTESVILLE, October 20, 1911.

To His Excellency, Hon. Wm. Hodges Mann, Governor of Virginia, and Chairman of the State Geological Commission:

SIR:—I have the honor to transmit herewith for publication, as Bulletin No. VI of the Virginia Geological Survey Series of Reports, a Biennial Report on the Mineral Production of Virginia during the Calendar Years 1909 and 1910, prepared by the Director of the Survey. In this report is given full information descriptive of the mining industry in Virginia during the calendar years 1909 and 1910.

Respectfully submitted,
THOMAS L. WATSON,
Director.

INTRODUCTION

Virginia is possessed of an abundance and variety of mineral materials. Many of these have been worked since early colonial days, especially the coal, iron ores, and brick clays. About 40 materials are now exploited, many of them on a large scale, which afford a basis of important commercial enterprises, and give to the State prominence in a varied and extensive mining industry. Most of the materials now produced can be developed still further with an increased production in future years. Some of these have been developed within recent years, and others still have not yet been exploited.

This bulletin gives full information descriptive of the mining industry in Virginia during the calendar years 1909 and 1910, including a brief treatment of the distribution, occurrence, development, and production of the mineral materials of the State. It has been prepared with the hope that it will be of service to those now engaged in exploitation of our resources, or otherwise interested in them. The statistics of mineral production in Virginia for the calendar year 1909 were collected by the Federal Survey in coöperation with the Bureau of the Census and furnished by courtesy of the Federal Survey to the Virginia Geological Survey. The statistics for the calendar year 1910 were collected by the Virginia Geological Survey in coöperation with the United States Geological Survey. The total number of productive operations is large, including a variety of subjects, as is indicated in the tables of annual production below. The aggregate value of their output in 1910, according to returns received at the State Survey office, amounted to $22,755,161.

The statistics of production and value of the mineral resources of Virginia for 1909 and 1910 are given below in tabular form. The figures are well above the totals of most of the materials recorded in previous years. The increase in 1909 and 1910 over that of 1908 is especially noticeable in the large industries and in many of the smaller ones.

There are given in the tables below the production and value of the various mineral materials in Virginia for the years 1906 to 1910, inclusive.

Mineral Production of Virginia in 1906.

Product	Unit of Measurement	Quantity	Value
Barytes	Short tons	11,775	$ 45,336
Clay	Short tons	2,903	24,354
Clay products			1,966,078
Coal	Short tons	4,254,879	4,183,991
Coke	Short tons	1,577,659	3,611,659
Ammonium sulphate	Pounds		[a]685,738
Coal tar	Gallons		
Gas, illuminating	Cubic feet		
Gas coke	Short tons		
Gold (mines report)	Fine ounces (Troy	717.50	14,832
Iron ores	Long tons	828,081	1,579,817
Iron, pig	Long tons	483,525	[a]8,591,000
Lime	Short tons	104,486	382,083
Manganese ores	Long tons	6,028	77,522
Millstones			15,611
Mineral waters	Gallons	1,997,207	418,908
Precious stones			500
Pyrite	Long tons	128,794	431,388
Sand and gravel	Short tons	335,178	121,951
Silver (mines report)	Fine ounces (Troy)	250	168
Slate			172,857
Stone			606,343
Talc and soapstone	Short tons	23,624	590,800
Zinc	Short tons	1,143	139,446
Other products			[b]990,432
Total value			$24,650,814

[a] Estimated.

[b] Includes asbestos, natural cement, Portland cement, gypsum, mica, ocher, pottery, quartz (flint), salt, sand-lime brick, and titanium.

Mineral Production of Virginia in 1907.

Product	Unit of Measurement	Quantity	Value
Barytes	Short tons	9,254	$ 32,833
Clay products			1,611,335
Coal	Short tons	4,710,895	4,807,533
Coke	Short tons	1,545,280	3,765,733
Ammonium sulphate	Pounds		1,165,821
Coal tar	Gallons		
Gas, illuminating	Cubic feet		
Gas, water	Cubic feet		
Gas coke	Short tons		
Copper	Pounds	57,008	11,402
Glass sand	Short tons	1,246	4,535
Gold	Fine ounces (Troy)	402	8,300
Iron ores	Long tons	786,856	1,538,920
Iron, pig	Long tons	478,771	8,963,000
Lead	Short tons	82	8,692
Lime	Short tons	115,155	447,307
Manganese ores	Long tons	4,604	56,469
Mica			1,014
Millstones			4,684
Mineral waters	Gallons	2,442,075	431,770
Precious stones			520
Pyrite	Long tons	124,740	372,586
Sand and gravel	Short tons	266,976	119,277
Silver	Fine ounces (Troy)	200	100
Slate			173,670
Stone			760,488
Talc and soapstone	Short tons	26,278	631,880
Zinc	Short tons	771	90,978
Other products			[a]774,809
Total value			$25,783,656

---

[a] Includes natural and Portland cement, feldspar, gypsum, ocher, rutile, and sand-lime brick.

Mineral Production of Virginia in 1908.

Product	Unit of Measurement	Quantity	Value
Clay	Short tons	442	$ 3,250
Clay products			1,536,907
Coal	Short tons	4,259,042	3,868,524
Coke	Short tons	1,162,051	2.121.980
Ammonium sulphate	Pounds		1,180,744
Coal tar	Gallons		
Gas, illuminating	Cubic feet		
Gas, water	Cubic feet		
Gas coke	Short tons		
Copper	Pounds	24,775	3,270
Gold (mines report)	Fine ounces (Troy)	118.57	2,451
Granite			321,530
Iron ores	Long tons	692,223	1,465,691
Iron, pig	Long tons	320,458	4.578,000
Lead	Short tons	38	3.200
Lime and cement	Barrels	1,629,178	775,660
Limestone			280,542
Manganese ores	Long tons	6,418	63,324
Mica	Pounds (sheet)	13,427	7.346
	Tons (scrap)	46	
Millstones and sandstone			10,554
Mineral waters	Gallons	[a]2,009,614	207.115
Pyrite	Long tons	116,340	435,522
Sand and gravel			119,095
Sand-lime brick	Thousands	6,181	36,934
Silver	Fine ounces (Troy)	236	125
Slate	Squares	41,678	194,356
Talc and soapstone	Short tons	19,616	458,252
Zinc	Short tons	705	66,315
Other products			[b]143.135
Total value			$17.883.822

[a] Exclusive of 119,672 gallons used for soft drinks.

[b] Includes barytes, feldspar, gypsum, mineral paint, and salt.

Mineral Production of Virginia in 1909.

Product	Unit of Measurement	Quantity	Value
Clay products			$ 1,957,367
Coal	Short tons	4,752,217	4,251,056
Coke	Short tons	1,347,478	2,415,769
Copper	Pounds	224,162	29,141
Gems and precious stones			2,500
Gold (mines report)	Fine ounces (Troy)	181.41	3,750
Granite			488,250
Iron ores	Long tons	837,847	1,693,188
Iron, pig	Long tons	391,134	5,550,000
Lime	Short tons	166,695	635,946
Limestone			342,656
Mica			4,600
Millstones and sandstone			40,922
Mineral waters	Gallons	1,504,530	203,455
Pyrite	Long tons	114,176	423,283
Sand and gravel	Short tons	847,476	281,177
Silver	Fine ounces (Troy)	4,825	2,509
Slate	Squares	40,880	180,775
Talc and soapstone	Short tons	26,511	523,942
Zinc	Short tons	58	6,298
Other products[a]			799,086
Total			$19,835,670

[a] Includes barytes, Portland cement, feldspar, gypsum, manganese ore, manganiferous ore, ocher, rutile, salt, and sand-lime brick.

Mineral Production of Virginia in 1910.

Product	Unit of Measurement	Quantity	Value
Clay products			$ 1,841,731
Coal	Short tons	6,507,997	5,877,486
Coke	Short tons	1,493,665	2,731,348
Copper	Pounds	5,402	686
Gold (mines report)	Fine ounces (Troy)	42.96	888
Granite			503.106
Iron ores	Long tons	903,377	1,845,144
Iron, pig	Long tons	444,976	6,150,000
Lead	Pounds	198,850	8,750
Lime	Short tons	141,257	563,567
Limestone			471,903
Manganese ores	Long tons	1,758	17,892
Millstones			5,273
Mineral waters[a]	Gallons	2,441,923	301,523
Pyrite	Long tons	140,106	525,437
Sand and gravel	Short tons	764,321	215,416
Silver	Fine ounces (Troy)	128	69
Slate	Squares	31,787	148,721
Talc and soapstone	Short tons	25,908	510,781
Zinc (spelter)	Pounds	1,588,112	85,758
Other products[b]			948,032
Total			$22,755.161

[a] Exclusive of 48,252 gallons used in the manufacture of soft drinks.

[b] Includes barytes, Portland cement, feldspar, gypsum, infusorial earth, manganiferous ore, ocher, rutile, sand-lime brick, and salt.

PRELIMINARY GENERALITIES

GEOGRAPHIC POSITION OF VIRGINIA.

The State of Virginia is situated on the Atlantic slope of the Appalachian Mountains, halfway between Maine and Florida. It is included between the parallels 36° 31′ and 39° 27′ north latitude, and between the meridians 75° 13′ and 83° 37′ west longitude, extending from the sea-coast westward beyond the Great Valley to the Alleghany Front. The extreme length of the State from the Atlantic border to Kentucky is 476 miles, and the greatest width from north to south is 192 miles; its area is 42,450 square miles. Of this area, 2,325 square miles are covered with water, giving 40,125 square miles of land surface. Its principal inland waters are the Chesapeake and Mobjack bays, Hampton Roads, and Lake Drummond. Except in the eastern section, no navigable streams traverse the State, and transportation is necessarily limited to railways.

SURFACE FEATURES OF THE STATE.[a]

Considered with reference to its surface features Virginia is divided into three major provinces: (1) An eastern plain region usually designated the Coastal Plain or Tidewater region; (2) a central or plateau region designated the Piedmont Plateau; and (3) a western or mountain region, designated the Appalachian Mountains province. The boundaries of these provinces are indicated on map, figure 1, page 8.

The three major provinces of the State differ markedly in the nature and origin of surface features, and in the age and kinds of rocks. They are intimately related to the geologic structure, and hence have an important bearing upon the mineral resources of the State. These are considered very briefly in order below.

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[a] A fuller discussion of this subject is contained in Bull. No. I-A of the State Geological Survey, 1909.

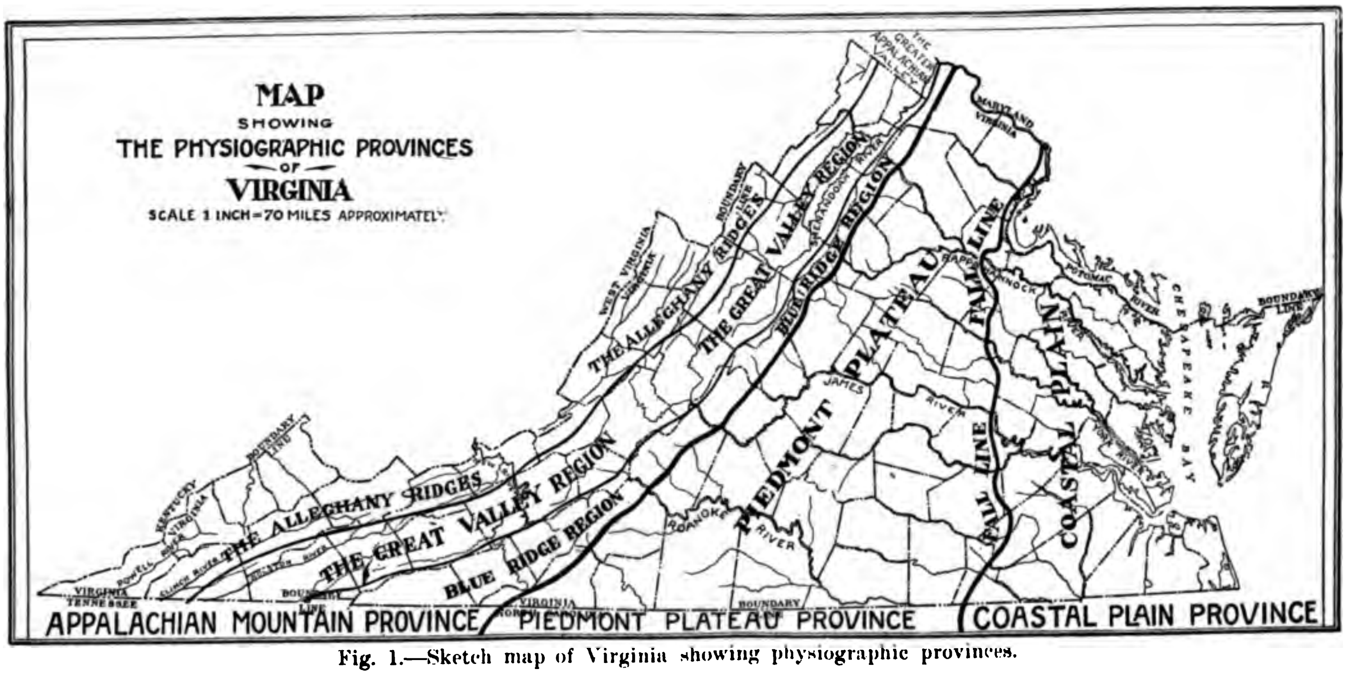

Fig. 1.—Sketch map of Virginia showing physiographic provinces.

The Coastal Plain Province.

The Virginia Coastal Plain province, the most easterly of the three larger physiographic provinces, and comprising approximately one-fourth of the total area of the State, is separated from the higher-lying Piedmont Plateau province on the west and the deep Atlantic Ocean basin on the east. The boundary of the Coastal Plain to the eastward is marked by the steep slope of the continental shelf, which lies from 30 to 50 miles east of the present shore-line. The western limit of the Coastal Plain is defined by the belt of metamorphic crystalline rocks known as the Piedmont Plateau province. The Virginia Coastal Plain region is more than 100 miles wide, and includes approximately 9,500 square miles of territory, or about one-fourth the total area of the State.

Because of marked geologic differences in the two provinces, the larger streams, and many of the smaller ones, are characterized by falls or rapids where they cross the western margin of the Coastal Plain, and they always show a marked decrease in the velocity of their currents from this point eastward. For this reason, the name "fall-line" has been given to this boundary, the position of which is marked on the accompanying map, figure 1, page 8.

The Coastal Plain region, characterized by broad, level-topped stretches of country of low relief, gradually declines in slope from the Piedmont border to the shore-line. The deposits consist chiefly of unconsolidated beds of sand, gravel, clay and marl, which may be locally indurated by a cement either of iron oxide or carbonate of lime. These indurated ledges in the vicinity of Aquia Creek and, in places, southward along the western margin representing the oldest formation of the Coastal Plain series, have afforded sandstone suitable for building purposes. The beds strike in general from north to south, although some variation occurs, with a low but variable easterly dip. In age, the Coastal Plain beds range from Lower Cretaceous to Quaternary.

The Chesapeake Bay affords unparalleled transportation facilities, and its principal tributaries, the Potomac, Rappahannock, York, and James rivers, give access to vessels as far westward as the Piedmont border—the "fall-line."

The Piedmont Plateau Province.

The Piedmont Plateau province lies between the Coastal Plain and the Appalachian Mountains. It extends from the eastern slope of the Blue Ridge eastward to the western margin of the Coastal Plain, and it widens southward (map, figure 1, page 8). Its width increases from about 40 miles in the northern portion along the Potomac River to nearly 175 miles along the Virginia-Carolina boundary. The sediments of the Coastal Plain lie across the bevelled edges of the crystalline rocks of the Piedmont, presenting such marked stratigraphic and lithologic contrast that the geologic boundary between the two provinces is sharply defined. The transition on the west is less sudden and well marked.

The Piedmont province contains a greater variety of mineral resources than either of the other two provinces. In general, the surface of the Plateau has a gentle southeastward slope from an average altitude of 1,000 feet along the western margin to from 200 to 400 feet on the east, where the plateau rocks pass beneath the Coastal Plain sediments. The topography of the plateau is that of a more or less smooth, broadly rolling or undulating upland of moderate elevation, into which the streams have rather deeply sunk their channels.

The drainage of the region is to the southeast into the Atlantic waters, and the major streams which traverse the plateau are the Potomac, Rappahannock, James, and Roanoke rivers.

The rocks of the Piedmont region are the oldest in the State and, excepting the areas of Triassic rocks, they are all crystalline. They comprise both sedimentary and igneous masses usually greatly altered from metamorphism. The region is made up of a complex of schists, gneisses, and granites, with, in places, areas of slate, quartzite, and limestone. This complex is intersected by intrusions of basic eruptive rocks belonging to several different types. Over parts of the eastern and central portions of the region are areas of altered volcano-sedimentary rocks which extend southwestward into North Carolina.

The age of the rocks of the region, excepting the areas of Triassic rocks, ranges from probable Archean to early Paleozoic.

The Appalachian Mountains Province.

The Appalachian Mountains province embraces the western portion of the State. Its eastern boundary is the southeastern slope of the Blue Ridge and its western limits are artificially drawn in the western boundary of the State. This province, like the Piedmont Plateau and Coastal Plain, extends northeast and southwest far beyond the limits of Virginia.

The topography of the Appalachian province is varied and picturesque. Three subdivisions of the province are recognized which, named from east to west, are: (1) The Blue Ridge; (2) the Great Valley; and (3) the Alleghany Ridges. The limits of these subdivisions are indicated on the map, figure 1, page 8.

The Blue Ridge, which forms the eastern boundary of the Appalachian province, maintains an uneven and knobby crest entirely across the State, in a northeast-southwest direction, and has an average elevation of not less than 2,000 feet above tide-level. The Blue Ridge is composed largely of pre-Cambrian rocks, represented in part, at least, by various igneous types, but sandstones and shales of Cambrian age are exposed along the western slope. It is a natural dividing line between the Paleozoic sediments comprising sandstones, limestones, and shales on the west, and the pre-Paleozoic and other rocks on the east.

The two most westerly sub-provinces, the Valley and the Alleghany Ridges, bounded by the two principal ranges, the Blue Ridge and the Alleghany Front, on the southeast and northwest, respectively, are here treated together under the Greater Valley region. Considered broadly, the Greater Valley region is composed of narrow valleys and linear ridges arranged in more or less complex relations. It is composed throughout of Paleozoic sediments, which range in age from Cambrian to Carboniferous. The principal rock-types include limestone, shale, and sandstone.

The rocks composing the Greater Valley region have been folded and faulted and subsequently greatly eroded. As a result of the folding and subsequent erosion, the edges of the formation form linear ridges and valleys, developing the well-known Appalachian type of topography.

EFFECTS OF WEATHERING AND EROSION.

The surface rocks over all parts of Virginia show some effects from atmospheric action. Of the three major provinces of the State described above, the Coastal Plain, on account of its very recent geologic history, has suffered the least. The remaining two provinces, Piedmont Plateau and Appalachian Mountains, bear striking evidence over all their parts of profound decay and erosion, which have resulted in the removal of vast quantities of rock material. Just how much of their surface has been lowered, or what vertical thickness of material has been removed from these land areas and carried seaward, would probably be very difficult to say, but that it has been large can not be doubted. Because of its greater geologic age and the vast length of time it has been a land area, the Piedmont Plateau has probably suffered the removal of the greatest thickness of material.

Through this process of weathering a mantle of varying thickness of decayed rock material overlies the still fresh or sound rock, except where the erosive action has not been too excessive and the slopes too steep for its accumulation. This residual material is loose and porous or incoherent, consisting usually of clay, sand and gravel, and on the immediate surface forms soil. On depth it passes by imperceptible gradation into the hard and fresh unaltered rock. The thickness of residual material varies from a few inches to, in extreme cases, 100 feet. Over many parts of the State, exposures of the hard rock are rare, except along the stream courses where the mantle has been cut through by erosion.

This process of rock decay is of very great economic importance. Workable ore deposits have been formed by it from sparsely disseminated and non-workable mineral matter in the original rocks. This is best illustrated in the manganese deposits, in a part of the iron and zinc deposits, and in other ore deposits of the State.

DIVERSITY OF RESOURCES.

There is probably no state in the Union, of the same area as Virginia, that can show a greater diversity in geologic resources. This is confirmed by the actual exploitation thus far made, and it might be naturally inferred from the position which the State occupies with reference to disturbed and undisturbed areas as described above. As indicated above and from an examination of the geologic map, the State stretches from the Atlantic coast westward nearly entirely across the Appalachian Mountain system. Within this area are found rocks ranging in age from pre-Cambrian to Recent, and representing all the principal divisions of geologic time. Equally as great a variety of rock-types, both sedimentary and igneous, of structure which characterizes both profoundly disturbed and undisturbed rock masses, and of topography, is shown.

The mineral products[a] that have been mined and quarried in Virginia are discussed in this bulletin in the following order: Iron ores, manganese ores, gold and silver, copper, lead and zinc, tin, nickel and cobalt, coal and coke, clay and clay products, lime and cement, sand and gravel, sand-lime brick, stone (granite, marble, limestone, sandstone, slate, crushed stone, and furnace flux), abrasive materials (corundum, emery, and millstones), silica (quartz, chert, and diatomaceous earth), mica, feldspar, asbestos, talc and soapstone, barytes, gypsum, salt, mineral paints, marl, pyrite and pyrrhotite, arsenic, phosphate, graphite, rutile (titanium), mineral waters, and precious stones (quartz, garnet, allanite, kyanite, fluorite, feldspar, microlite, apatite, beryl, columbite, and helvite).

IRON ORES AND PIG IRON.

The present commercial deposits of iron ore in Virginia are confined to the Piedmont and Appalachian regions. The iron ores of the Piedmont region occur in metamorphic crystalline rocks of unknown age, probably pre-Cambrian in large part; those of the Appalachian region occur in sedimentary rocks of Paleozoic age, or the residual material derived from them.

The iron minerals used as ores of the metal in the State are, chemically, oxides, of which there are three important types, limonite (brown hematite), red hematite, and magnetite. Of these, the brown hematite has been and is the principal source of the metal, as indicated in the table on page 21. The sulphides and carbonate, especially the former, occur in many places, but they do not form as yet an important source of the metal.

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[a] A map of Virginia showing location of mines and quarries was published by the State Geological Survey in 1909 and partly distributed with Bull. No. I-A. Scale of map, 12 miles equals 1 inch.

The iron ores of Virginia may be classified as follows:[a]

PIEDMONT REGION:

1. Hematite. Specular hematite associated with magnetite in the James River valley.
2. Brown ore. Gossan ore forming a capping of pyrrhotite deposits in southwestern Virginia, and pyrite deposits in northern and central Virginia.
3. Magnetite. Associated with gneisses, schists, and crystalline limestones, in central and southwestern Virginia, and with basic intrusions in the Blue Ridge.

APPALACHIAN REGION:

1. Hematite.
    - (a) Siliceous specular hematite interbedded with lower Cambrian shale and quartzite in the Blue Ridge.
    - (b) Fossil (red) hematite interbedded with shale and sandstone of Clinton (Rockwood) formation in western and southwestern Virginia.
2. Brown ore.
    - (a) "Mountain" ores of the Blue Ridge and the New River district, associated with lower Cambrian quartzite and with residual material above it derived from the quartzite and from the overlying formations.
    - (b) "Valley" ores associated with residual material of the Shady limestone in the New River district. A few deposits of this nature occur with other limestones of the Shenandoah group along the Blue Ridge.
    - (c) Oriskany ores replacing the Lewistown limestone directly under the "Monterey" (Oriskany) sandstone in the western part of the Appalachian region.
3. Magnetite. Magnetite and hematite associated with limonite and iron carbonate in the upper part of the Shenandoah group locally in southwestern Virginia.
4. Iron carbonate. Iron carbonate occurring with limestone magnetite in the upper part of the Shenandoah group locally in southwestern Virginia, and as ironstone concretions in the Martinsburg and Romney shales.

In recent years, the iron ores of the Piedmont region have contributed only a very minor part of the total production of the ores in the State, though small quantities of magnetite and limonite (brown ore) are produced annually from this region.

Magnetite deposits, usually having the form of lenticular beds or elongated pods and interlaminated with gneisses, schists and, in places, limestones, are widely distributed through the Piedmont region.

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[a] Harder, E. C. Bulletin 380, U. S. Geological Survey, 1909, pp. 216-217. The sulphide types of iron ores are omitted from the scheme of classification, as they have not yet contributed to the production of metal in Virginia, but are utilized in acid making, and are treated under Pyrite and Pyrrhotite on pages 108-111.

They occur in Albemarle, Amherst, Appomattox, Buckingham, Fluvanna, Franklin, Grayson, Louisa, Nelson, Patrick Henry, and Pittsylvania counties. The James River valley area below Lynchburg was a principal iron-producing district in the State about a hundred years ago, and was exploited again about 1880. In recent years, the magnetite ore at Pittsville in Pittsylvania County has been the most extensively mined in the Piedmont region. The ore body has a thickness of 12 feet and occurs between crystalline limestone and mica schist. Magnetite has been mined near Rocky Mount, in Franklin County, and west of Goblintown Creek in Patrick County. The magnetite deposits vary in thickness up to 30 feet and more, and they show much irregularity (pinching and swelling) on both the strike and the dip. They vary greatly in composition, from bodies containing practically all iron ore to those made up largely of gangue minerals with but little ore. They include both non-titaniferous and titaniferous types.

Brown (gossan) ore, resulting from the oxidation of pyrite and pyrrhotite above groundwater level, has wide distribution through the Piedmont region. It occurs capping the pyrite bodies in metamorphic crystalline schists of unknown age, of Buckingham, Louisa, Prince William, Spottsylvania, and Stafford counties, and formed the basis for the first iron industry in Virginia; but it has not been mined in recent years. Similar ore occurs in Carroll, Floyd, Franklin, and Grayson counties, forming the capping of pyrrhotite deposits in metamorphic crystalline schists.

The "Great Gossan Lead" of Carroll-Floyd-Grayson counties is the most extensive one of the gossan leads. It is quite variable in width, ranging from a few feet up to more than 150 feet. The gossan consists of light brown or yellow limonite, which extends to a depth of from 10 to 60 feet, and has been mined in many places.

The brown iron ores of the Appalachian region, which include the "mountain," valley or limestone, and Oriskany ores, are commercially the most important ores in Virginia. The specular hematites of the Blue Ridge are second in importance, the Clinton fossil ores third, and the remaining types are of minor importance. These types of ores are briefly described below.

Specular hematite occurs in workable quantity along the Blue Ridge in Bedford, Botetourt, and Roanoke counties. It occurs interbedded with lower Cambrian quartzite and shale, and is believed to be sedimentary in origin. The ore bed is of variable thickness and has been worked at eight localities, as follows:[a] "The Arcadia and Wood mines, about 4 miles southeast of Buchanan; the Ironville and Dewey mines, near Montvale; the Lemon, Grubb-Specular and Edith mines, about 3 miles northwest of Blue Ridge Springs; and the Griffin-Specular mine, about 5 miles south of Roanoke. Of these, the Arcadia, Wood, Dewey, and Edith mines are at present in operation." The ore is a very siliceous dark-red hematite, in which the iron content ranges from less than 35 per cent to 45 per cent, and the silica content from 30 to 40 per cent.[b]

Fossil hematite, interbedded with shale and sandstone of the Clinton (Rockwood) formation of the Silurian system, occurs in workable quantity in Alleghany, Lee, and Wise counties. In Alleghany County, fossil ore has been mined on the southeast slope of Horse Mountain, 3 miles southeast of Lowmoor, and in the bluff northeast of Jackson River at Iron Gate. Only one workable bed of ore is known, which averages less than two feet in thickness. The ore mined is of the soft variety from which the calcium carbonate has been removed by surface waters, and it carries 46 to 57 per cent of metallic iron. According to Hayes,[c] nearly 90,000 tons of fossil ore were shipped in 1907 from mines in the Alleghany County district.

In the Lee-Wise counties district of southwest Virginia, fossil hematite ore is mined south of Big Stone Gap on Wallen Ridge, and in Powell Valley, and southwest of Pennington Gap along Poor Valley ridge. The Yeary, Irondale, Keystone, and Oreton mines have been opened south of Big Stone Gap, and the Pennington, Lavine, Ben Hur, Truro, Noes Siding, Grabill, Boones Path, and Ewing mines are opened along Poor Valley ridge. In the southwest Virginia district there are three ore beds which have been mined, ranging in thickness from 6 inches to 2.5 feet. The ores mined are chiefly of the soft variety, and are of lower grade than those of the Alleghany County district.

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[a] Harder, E. C. Bulletin 380, U. S. Geological Survey, 1909, p. 225.
[b] Ibid., pp. 227 and 228.
[c] Hayes, C. W. Bulletin 394, U. S. Geological Survey, 1909, p. 88.

The "mountain" brown ores, so called because of their occurrence along the flanks or at the base of a sandstone or quartzite ridge, extend along the west slope of the Blue Ridge from near Front Royal, in Warren County, to a point south of Roanoke, and along the east side of the New River-Cripple Creek district, in Pulaski County, and along and near to the Wythe-Carroll counties boundary. The ore deposits are associated with Cambrian quartzite or its residual material, usually the latter, show great variation in form and texture, and range in iron content from 35 to 50 per cent and in silica content from 10 to 30 per cent, with usually high manganese and phosphorus. They are of lower grade than the valley or limestone brown ores, and are regarded as concentrations by meteoric water, the iron having been derived largely if not entirely from the overlying shale and limestone formations.

The valley or limestone brown ores are distributed at intervals throughout the Valley region west of the Blue Ridge, in association with the residual clays derived from the limestone by processes of decay. The principal occurrence of these ores is in the New River-Cripple Creek district of Wythe and Pulaski counties, in residual clays derived from the Shady (lower member of the Shenandoah group) limestone. A large number of mines have been operated in this district.

In the northern and central Valley region the limestone brown ores are not so abundant, there being less than a dozen deposits that have been worked between Roanoke and the Maryland boundary. The ores of this region, called the Blue Ridge belt, occur in residual clays derived from the Natural Bridge limestone.

The ore is disseminated through the residual clay in varying concentrations ranging from large porous masses down to pellets the size of a pea. The proportion of clay to ore in the workable deposits varies considerably, usually from 5 to 1 to 25 to 1.[a] The ores are usually richer than the "mountain" ores ranging in iron content from 40 to 55 per cent, and in silica content from 5 to 20 per cent, with usually less than 1 per cent of manganese and enough phosphorus to be classed as a non-Bessemer ore.

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[a] Harder, E. C. Bulletin 380, U. S. Geological Survey, 1909, p. 244.

The valley or limestone brown ores are residual deposits, the iron of which was originally disseminated through the rocks and, under favorable conditions, has been concentrated during the process of weathering and erosion.

The Oriskany brown ores are the most important of the iron ores mined at present in Virginia. The principal district of Oriskany ores includes the counties of Alleghany, Botetourt, and Craig, from which nearly all the ore mined of this type is produced. Minor deposits occur on Draper Mountain, in Pulaski and Wythe counties; on Peters Mountain, Giles County; in the Buffalo Gap area, Augusta County; in Massanutten Mountain, Shenandoah County; and on North Mountain, in Shenandoah and Frederick counties.[a]

These ores are limited to a definite horizon, in the Lewistown (Helderbergian) limestone, immediately below the Monterey (Oriskany) sandstone. They represent replacements of the upper portion of the limestone. The ore was derived from the overlying Devonian black shales by meteoric waters. Where the shales were of sufficient thickness and the underlying Monterey sandstone sufficiently thin and fractured, the iron-bearing solutions penetrated into the underlying limestone and, under favorable conditions, replaced the calcium carbonate by iron oxide, forming the ore bodies.

The ore deposits are continuous for considerable distances along the strike with great variations in thickness of the ore bodies shown, ranging up to 75 feet with a probable average of 15 to 25 feet. The ore, usually fairly solid but frequently porous with the cavities containing clay, ranges between 35 and 50 per cent of metallic iron. They are usually high in silica and manganese, resembling in this particular the "mountain" ores.

The principal Oriskany brown ore mines[b] in the State are Liberty and Van Buren Furnace mines, in Shenandoah County; the Buffalo Gap and Ferrol mines, in Augusta County; the Victoria and Longdale mines, north of Longdale, Alleghany County; the Dolly Ann,

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[a] Harder, E. C. Ibid., p. 246.

[b] Op. cit., p. 248.

Iron Mountain, and Stack mines, near Covington, Alleghany County; the Lowmoor and Rich Patch mines, near Lowmoor, Alleghany County; the Jordan mines, on Potts Creek, Alleghany County; the Callie, Wilton and Circle mines, near Glen Wilton, Botetourt County; the Oriskany and Fenwick mines, in Botetourt and Craig counties, near Oriskany; the Gala mines, near Dagger Spring, Botetourt County; the Clayton and Peak Knob mines, near Pulaski, Pulaski County; and the Locust Hill mine, near Max Meadows, Wythe County.

The remaining types of Appalachian iron ores in Virginia, including the limestone magnetite and iron carbonate ores, are of minor importance. The principal deposits of the limestone magnetite ores. so far known, occur near Big Sandy Junction, in Giles County, and near Abingdon, in Washington County, with smaller deposits elsewhere in southwest Virginia. Iron carbonate is reported in minable quantity from only one locality, namely, near Abingdon, in Washington County, in association with limestone magnetite ore.

The iron ores of the State are under investigation by the Virginia Geological Survey, after the completion of which a detailed report will be published.

The iron ore mining industry in Virginia showed a decided increase in 1909, the figures of production being 837,847 long tons, valued at $1,693,188, as against 692,223 long tons, valued at $1,465,691 in 1908. This was an increase over the 1908 production, of 145,624 long tons or 21.03 per cent in quantity, and $227,497 or 15.52 per cent in value. The average price per tone of ore in 1909 was $2.02.

The production of iron ores in Virginia during 1910 amounted to 903,377 long tons, valued at $1,845,144. These figures represent an increase over the production for 1909, of 65,530 long tons or 7.82 per cent in quantity, and $151,956 or 8.97 per cent in value. The average price per ton of the iron ore mined in Virginia during 1910 was $2.04. The 1910 production of iron ores in the State represented the output of forty-nine mines distributed among fourteen producers operating in the same number of counties (14). The counties producing iron ore in the State during 1910 were as follows: Alleghany, Augusta, Bedford, Botetourt, Carroll, Craig, Lee, Pittsylvania, Pulaski, Roanoke, Rockbridge, Smyth, Washington, and Wythe.

There is given in the table below the total production of iron ore in Virginia by varieties, from 1900 to 1910, inclusive. It will be observed that brown hematite is vastly the most important, producing at present 90.89+ per cent of the total. The next in order of importance is red hematite, which contributed, in 1910, a little over 9 per cent of the total production, while magnetite for the same year amounted to less than a half of one per cent.

Production of Iron Ore in Virginia, by Varieties, 1900-1910, in long tons.

Year	Brown hematite	Red hematite	Magnetite	Total quantity	Total value
1900[a]	918,157	3,664	....	921,821	$1,489,318
1901[a]	910,214	13,156	2,024	925,394	1,466,423
1902[a]	953,128	31,677	3,153	987,958	1,667,456
1903[a]	764,948	31,609	4,604	801,161	1,432,624
1904[a]	528,853	17,952	3,448	550,253	951,478
1905	704,470	35,357	518	740,345	1,256,428
1906	735,204	92,257	620	828,081	1,579,817
1907	696,518	89,867	471	786,856	1,538,920
1908	626,910	64,323	990	692,223	1,465,691
1909	762,937	72,955	1,955	837,847	1,693,188
1910	821,131	81,647	599	903,377	1,845,144

[a] Includes West Virginia, but practically the total production was from Virginia.

A good idea of the distribution of the different varieties of iron ore produced in Virginia in 1910 may be gained from the table below, in which the total production is classified by varieties and counties. Brown hematite, which constitutes at present the chief ore, comes mostly from the Appalachian counties west of the Blue Ridge, with only a minor production from the counties in the crystalline area. The same is true for the production of hematite, which now stands next in importance to brown hematite. Deposits of magnetite are widely distributed through the crystalline area, which form important reserves of iron ore, but the production of magnetite in the State has been very small and of minor importance.

Production of Iron Ore in Virginia, by Counties and Varieties, 1910, in long tons.

County	Brown hematite Long tons	Value	Red hematite Long tons	Value
Alleghany	234,772	$ 582,068	(a)	(a)
Augusta Bedford Carroll Craig	147,298	272,768	(a)	(a)
Botetourt	168,148	398,928		
Lee	....	....	(a)	(a)
Pittsylvania Pulaski Roanoke Smyth	127,185	202,099		
Rockbridge	14,001	31,216		
Washington Wythe	130,326[b]	215,939		
Total	821,730	$1,703,018	81,647	$ 142,126

[a] Included under total in order to avoid disclosing individual production.
[b] Includes 599 tons of magnetite.

The average price per long ton of the different varieties of iron ore produced in Virginia during 1910 follows: Brown hematite $2.07, red hematite $1.74, and magnetite $1.50. These prices represent the value of the ore at the mouth of the mine, and are taken directly from the replies of the producers.

The production of pig iron in Virginia during 1909 amounted to 391,134 long tons, valued at $5,550,000, as compared with 320,458 long tons, valued at $4,578,000 in 1908, an increase in quantity of 70,676 long tons or 22.05 per cent, and in value of $972,000 or 21.21 per cent. The 1910 production of pig iron in Virginia amounted to 444,976 long tons, valued at $6,150,000, an increase over the production of the preceding year of 53,842 long tons in quantity, and $600,000 in value.

There is given in the table below the production of pig iron in Virginia for the years 1905 to 1910, inclusive.

Production of Pig Iron in Virginia, by years, 1905-1910.

Year	Quantity Long tons	Value	Value per ton
1905	510,210	$7,540,000[a]	$14.78
1906	483,525	8,591,000[a]	17.77
1907	478,771	8,963,000	18.72
1908	320,458[b]	4,578,000	14.29
1909	391,134[b]	5,550,000	14.19
1910	444,976[b]	6,150,000	13.82

[a] Estimated.

[b] Birkinbine, J. Personal communication.

LIST OF IRON ORE OPERATORS

OPERATOR	OFFICE	MINE
Barr Ore & Iron Corporation	Pittsville	Pittsville.
Bentonville Mining Co	Philadelphia, Pa	Bentonville
Black, H. A and J. L	Staunton	Stuarts Draft
Bland Iron & Coal Co	Wytheville	Bland County
Boone's Path Iron Co	Baltimore, Md	Rose Hill Station
Botetourt Mineral & Mining Co	Fincastle	
Buena Vista Iron Co., Inc	Johnstown, Pa	Buena Vista
Catawba Mining & Manufacturing Co	Roanoke	
Coots, Graham	Basic City	Staunton
Crescent Iron Ore Co	New York, N. Y	Stanley and Stanleyton
Crowder, Delaney & Miller	Covington	Clifton Forge
Elliotts Knob Coal & Iron Co	Buffalo Gap	
Eureka Manganese Co	Stanleyton	Stanleyton
Franklin, G. H	Brights	Brights
Goshen Iron Co., Lessee, Chapman Iron, Coal & Coke Co	Goshen	Clifton Forge
Graham Heirs, Part Owners of Virginia Iron, Coal & Coke Co	Graham Forge	
Halser, Ira F	Troutville	Troutville
Hatcher & Sheaffer	Pulaski	Peak Knob and Pulaski
Horneck Construction Co	Cumberl'd Gap, Tenn	Ben Hur and Jonesville
Indian Camp Mining Co	Max Meadows	Ivanhoe
Ivanhoe Furnace Co	Pittsburg, Pa	Abingdon Austinville Fries Ivanhoe
Keystone Coal & Iron Co	Philadelphia, Pa	Oreton
Laing, J. B	Lewisburg, W. Va., or Newcastle.	
Little, J. F	Newcastle	Waitsville
Lobdell Car Wheel Co	Wilmington, Del	White Rock Furnace
Longdale Iron Co	Longdale	Australia
Lowmoor Iron Co. of Virginia	Lowmoor	Backbone, Covington, Lowmoor, and Newcastle
McLean, James G	Pittsburg, Pa	Raphine
Manganese Iron & Coal Co	Newcastle	Newcastle
Oriskany Ore & Iron Corporation, Lessees Alleghany Ore & Iron Co	Iron Gate	Lignite and Vesuvius

OPERATOR	OFFICE	MINE
Persinger, J. W	Buena Vista	Rich Patch
Pittsville Mining Co	Pittsville	Pittsville
Poplar Camp Mining Co	Max Meadows	Ivanhoe and Max Meadows
Princess Furnace Co	Glen Wilton	Glen Wilton
Pulaski Iron Co	Pulaski	Allisonia, Buchanan, Cripple Creek, Foster Falls, and Pulaski
Sanders & St. Clair	Troutville	Troutville
Scherr, A. C. and others	Charleston, W. Va	Grottoes
Seibel, H. J	Happy Creek	Happy Creek
Spoor, W. M	Abingdon	Adwolf
Thrush, H. H	Front Royal	Limeton
Union Iron & Steel Co., L. O. Pettit, Receiver	Big Stone Gap	Ewing
Utah-Virginia Mining Corporation	Salt Lake City, Utah	Troutville
Vesuvius Mining Co	Baltimore, Md	Greenville
Virginia Clay & Material Co	Farmville	Farmville
Virginia Iron, Coal & Coke Co	Roanoke	Allisonia Baker Mines Barren Springs Blue Ridge Springs Clark Summit Cotopaxi Cripple Creek Foster Falls Graham Interior Max Meadows Montvale Ogden Reed Island Roanoke Speedwell
Virginia Iron & Lumber Co	Philadelphia, Pa	
Virginia Ore & Iron Co	Baltimore, Md	Berryville
Watts, Sterling	Max Meadows	Austinville
West End Furnace Co	Roanoke	Allisonia
Williams & Son, John T	Bristol, Va.-Tenn	Bonsacks
Willis & Nutson	Hamakertown	
Wissler Mining Co	LaFollette, Tenn	Ivanhoe
Zinns Iron Mining Co	Washington, Pa	Vesuvius

MANGANESE ORES.

Virginia has more known deposits of manganese, they extend over a larger territory, a larger number of localities have been worked, and more manganese has been produced than in any other state in the Union. Manganese ores occur in each of the three major geologic provinces of the State, namely, the Coastal Plain or Tidewater belt, the Piedmont province or crystalline area, and the Appalachian Mountains province or Paleozoic area. Of these the Mountain (Valley) province has yielded the principal production, with extensive operations and a large total production from the Piedmont province. Only a slight production has come from the eastern or Coastal Plain province.

Manganese occurs natively in a variety of mineral combinations but only the oxides of the metal are of commercial importance in Virginia. Of these, pyrolusite and psilomelane greatly predominate with, in places, much of the earthy oxide, wad. These different oxides often occur admixed in varying proportions. The ore is frequently partially or entirely crystalline, of a dark steel-blue color, and the nodular (kidney) type, which usually prevails, often displays the complete or partially layered structure of concretionary masses.

The manganese ores are usually found imbedded in the residual clays which overlie the rocks, from which the clays have been derived by the usual processes of decay. The underlying rock yielding the ore-bearing clays may be of sedimentary or igneous origin, and may be the usual consolidated sediments, or a metamorphic crystalline type.

The ore is distributed through the clays in an irregular manner in the form of pockets or lenticular masses, rarely as distinct beds; as veinlets and stringers cutting the clays in all directions; as single nodules and masses, ranging in weight up to 500 pounds, assembled in the clays; as small disseminated grains scattered through the clays; as breccia ore in large masses; and as probable replacement and cavity fillings in sandstone or sandy clay. In places, both in the Piedmont and Valley regions, the ore distribution conforms in a general way to the bedding of the inclosing clays; frequently, however, this is obscured and the ore bodies indiscriminately cut the clays in all directions.

In the Piedmont region where the residual clays have been derived from the decay of crystalline schists, and the original schistosity of the rocks preserved in the clays, the ore frequently conforms with the foliation and is disposed in thin stringers and sheets much after the manner of interleaving. The pockets show much variation in size and number, ranging from small nests to bodies yielding many tons of ore. They are rarely composed of solid ore free from clay, but the ore forms thickly-studded nodules in the clays. The pockets may be closely spaced or they may occur at wide intervals, usually not connected, although at times stringers or irregular nodules may lead from one pocket to another.

The principal productive manganese deposits in Virginia are (1) those of the Piedmont region, occurring chiefly in Campbell and Nelson counties, northeast and south of Lynchburg; and (2) those of the Valley region occurring along the west slope of the Blue Ridge. Numerous mines have been worked in the Piedmont region.

In the Valley region the principal manganiferous ore belt lies along the west slope of the Blue Ridge. Workable deposits of manganese ores have been found in each county bordering on the western slope of the Blue Ridge. The Blue Ridge iron ore mines occur along this belt, many of which contain some manganese in the form of manganiferous iron ore, and similarly many of the manganese deposits contain some iron. The manganese ores are usually found embedded in residual clays derived from Cambrian ferriferous shales, which overlie the Cambrian quartzite. In other places over the Valley region, manganese ores occur similarly embedded in residual clays derived from limestone of Cambro-Ordovician age. The famous Crimora mine in Augusta County has produced more manganese ore than all other mines in the United States combined.

Virginia has always been the principal producer of manganese ores in the United States. The figures of production in 1909 were 1,334[a] long tons, valued at $14,275, as compared with 6,144 long tons, valued at $62,776 in 1908. This represents a loss of 4,810 long tons, or 78.3 per cent, in quantity, and $48,501, or 77.25 per cent, in value. There were 2 producers of manganese ores in 1909, operating in 2 counties. The production for 1910 was as follows: 2,059[a] long tons, valued at $18,509. These figures represent an increase, over the 1909 production, of 725 long tons in quantity, and $4,234 in value. There were four producers of manganese ore in 1910, and one of manganiferous ore. The production came from the following four counties: Augusta, Campbell, Rockingham, and Warren. In addition to the figures given above, 2,085 long tons of manganese ore were reported as stock on hand at the close of 1910.

There are given in the table below the figures of production and value of manganese ores in Virginia from 1903-1910, inclusive.

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[a] Includes small production of manganiferous ore.

Production and Value of Manganese Ores in Virginia, 1903-1910.

Year	Quantity Long tons	Value	Average value per ton
1903	1,801	$ 19,611	$10.89
1904	3,054	28,406	9.30
1905	3,947[a]	35,209	8.92
1906	6,028	77,522	12.86
1907	4,604	56,469	12.27
1908	6,144[b]	62,776	10.22
1909	1,334[c]	14,725	10.70
1910	2,059[c]	18,509	8.98

[a] In addition, 453 tons of tailings, valued at $406, were shipped.

[b] In addition, 274 tons of manganiferous iron ore were sold.

[c] Includes small production of manganiferous ore.

LIST OF MANGANESE ORE OPERATORS

OPERATOR	OFFICE	MINE
Atkins, Geo. M	Attoway	Attoway
Bear Pond Lumber, Coal & Oil Co	Gettysburg, Pa	Capon Roads
Benham, Wm. J	Philadelphia, Pa	Woodstock
Binswanger & Co., H. P	New York, N. Y	Woodstock
Cameron, Donald	Baltimore, Md	Woodstock
Carnahan, J. W	Wytheville	Rural Retreat
Cole, Hugh F	Chilhowie	Chilhowie
Cook & Son Mining Co., D. S	Wrightsville, Pa	Gala
Cox, Charles W., Assignee, Henry W. Poor & Co	New York, N. Y	Crimora
Cuthbert, W. R	Lynchburg	Evington
Dry Run Mining & Development Co	Norfolk	Compton
Eagle Cliff Mining Co	Atkins, R. F. D. No. 2	Ivanhoe
Etna Iron & Manganese Co	Lynchburg	Mt. Athos
Eureka Manganese Co	Stanleyton	Stanleyton
Evington Manganese Co	Evington	Evington
Forney Mining Co	Roanoke	
Harmon, C. H., Prop., Magie, H. M., Operator	Waynesboro	Crimora
Lackey, L. B	Happy Creek	Happy Creek
Lang, S. J	Harrisonburg	Middle River District
Loeb, Simon F	McKeesport, Pa	Otter River
McCormick, F. Olney	Philadelphia, Pa	Zepp
McCune, Samuel	Meadow Mills	Cedar Creek
McGovern, Wm., B. F. Buchanan, Lessee	Bristol, Tenn	Sugar Grove
Main, T. F	Wytheville	Wytheville
Manganese Corporation of Virginia	New York, N. Y	Vesuvius
Marchant, E. W	Attoway	Marion
Metal Manufacturing Co	Elkton	Elkton
Metallic Alloys Co	New York, N. Y	Lyndhurst
Midvale Mining Co., Inc., F. W. Schultz, Operator	Baltimore, Md	Midvale
National Manganese Corporation	Washington, D. C	Lyndhurst
Piedmont Manganese Co	Lynchburg	Mt. Athos
Pittsville Mining Co., E. R. Hutter, Proprietor	Pittsville	Pittsville
Poor & Co., Henry W	New York, N. Y	Crimora
Rockingham Mineral Co., Inc	Elkton and Pittsburg, Pa.	Elkton
Seibel, H. J., Jr., Prop., and Lackey, L. G., Supt	Philadelphia, Pa., and Happy Creek	Happy Creek
Southern Manganese Mining Co	Harrisonburg	Front Royal
Staley's Creek Manganese & Iron Co	Marion	Currin Valley
Steele Ore Co., care Royal Baking Powder Co	New York, N. Y	Stuarts Draft
Stoner, K. B	Fincastle	Troutville
Tate, James, D	Chilhowie	Marion
Weightman, Wm. (Hampton L. Carson, Attny. for Anne M. Walker)	Philadelphia, Pa	Mt. Athos

GOLD AND SILVER.

The Virginia Mining Company of New York, operating between the years 1831 and 1834 the Grasty tract of land in Orange County, was the first gold mining company incorporated in Virginia. In 1836, there was considerable activity in gold mining in the State, and the production was reasonably steady from the rediscovery in 1831 to 1850, the annual value being given between $50,000 and $100,000. Increased activity in gold mining in the State was manifested in the early fifties, but the Civil War almost completely stopped mining operations in Virginia and in the South generally. Considerable activity was again manifested in the Virginia gold fields after the close of the Civil War, and milling and reduction plants were erected at various points. Many of these attempts met with only small success and in most cases were abandoned, not because of the lack of ore, but because largely of bad mangement and inexperienced mining, together with a change from free milling to pyrite ores.

The principal gold-bearing areas are arranged in a belt which begins in Montgomery County, Maryland, and extends across Virginia in a southwestward direction to the North Carolina line. The belt varies in width from 15 to 25 miles, and is 200 miles long, with its best developed portion in Fauquier, Stafford, Culpeper, Orange, Spottsylvania, Louisa, Fluvanna, Goochland, and Buckingham counties. Gold is also found in Appomattox, Prince Edward, Charlotte, Halifax, and Pittsylvania counties, which mark the southwest extension of the principal belt. Excepting Halifax, which has been a producer for several years, no developments have been made in the last-named counties.

A smaller belt occurs on the west side of the Blue Ridge in Montgomery, Floyd, and Grayson counties, but is undeveloped and has proved of little economic importance.

Many of the mines in the principal belt have produced large quantities of gold, as shown in the United States mint returns, and have been rather extensively worked. Preparations are in progress for the resumption of mining at a number of the mines in the principal belt. During 1910 considerable interest was manifested at many places within the belt in exploiting old and new properties. The principal gold belt is crossed by innumerable streams bordered by placers, many of which have been worked over several times.

The principal rocks of the gold belt are micaceous schists and gneisses, often garnetiferous and chloritic, and in places hornblendic. They include both altered sediments and igneous masses. The prevailing strike is N. 20° E., and the dip is toward the east and southeast at varying angles, frequently steep, and in many cases nearly vertical. Granite masses and basic igneous rocks occur in the region, sometimes sheared from dynamic causes.

The gold-bearing veins are chiefly quartz, which vary in texture from large crystalline masses to very fine saccharoidal grains. In structure, they vary from massive to thin platy or schistose bodies, both usually penetrated by closely spaced irregular fractures. The principal metallic content is auriferous pyrite, which at times is copper-bearing and contains more or less admixed chalcopyrite. Within the weathered zone, extending from the surface down to local water-level and of varying depth, the quartz is more or less porous and discolored or stained with iron oxide from the oxidation of the sulphide minerals, and the liberation of free or elementary gold. Below the local water-level the veins are fresh, the sulphides are unaltered, and elementary gold is less frequent in occurrence. The early operations were confined largely to the oxidized portions of the veins which yielded a free-milling ore that was easy of treatment. Since then, operations chiefly include the mining of sulphurets or the sulphide bodies, which require a different metallurgical treatment of the ores in order to extract and recover the gold.

The gold-bearing veins conform in the main to the structure, strike and dip of the inclosing rocks, a fact which has caused various explanations to be advanced for their origin by different observers. Although the veins conform in the main to the dip and strike of the inclosing rocks, the correspondence is far from being exact, for they frequently cut the schists at small angles both in dip and strike.

Excepting quartz and pyrite, the gangue minerals in the gold veins of Virginia comprise the following species: Chalcopyrite, native copper, galena, mispickel (arsenopyrite), pyromorphite, tetrahedrite, tourmaline, vanadinite, sphalerite, pyrrhotite, and siderite. So far as the gangue minerals are concerned, the Virginia gold ores are entirely typical in character. The ores are quartzose deposits in which pyrite is usually present, chalcopyrite common, and mispickel and sphalerite are not rare.

In 1904, the production of gold and silver in Virginia was contributed to by eleven counties. From the United States mint returns for 1905, the gold production in Virginia increased in value, over 1904, $1,182; and silver decreased $3,779. In 1905, seven mines were reported producing, three of which were placer mines. According to Lindgren, the four deep mines yielded an estimated tonnage of 800, with an average value of $5.35 per ton in gold and silver. The production in 1906 showed an increase over that of 1905 of $9,850 in gold and $61 in silver. There were 9,565 short tones of siliceous ores raised which yielded an average extraction of $4.17 per ton. There was no reported production for the year from placer mines. In 1907, the total production of gold was valued at $8,288 and of silver $146, a decrease from that of 1906. According to McCaskey, seven mines reported a production, six of which were deep mines, yielding 26,822 short tons of ore. Of this, 1,128 short tons were siliceous ores which yielded an average extraction of $7.33 per ton in gold and silver; 25,044 short tons were siliceous and cupriferous sulphide ores, giving an extraction of $0.002 per ton in the precious metals; and the remainder were lead ores which yielded no gold or silver.

Four placers and four deep mines reported a production in 1908. According to McCaskey, the deep mines reported 12,877 tons of ore, 230 tons of which were siliceous gold ores, with an average value in precious metals of $7.135 per ton, and 1,896 tons were copper ores yielding $0.05 in precious metals and 12.4 pounds of copper per ton. Eight hundred (800) tons of lead ores yielded gold and silver valued at $0.28 and 95.2 pounds of lead per ton.

Virginia produced, in 1908, 118.57 fine ounces of gold valued at $2,451, and 236 fine ounces of silver valued at $125. This shows a decrease from the production of 1907 in gold of 283.43 fine ounces in quantity, and of $5,849 in value, and a decrease in silver of $21 in value, but an increase of 15 fine ounces in quantity. In 1909, the total production of gold was 181.41 fine ounces valued at $3,750, and of silver 4,825 fine ounces valued at $2,509, an increase in value over that of 1908 of $1,299 of gold and $2,384 of silver. Eight mines contributed to the production, five of which were placers and three deep mines. According to McCaskey, the deep mines yielded 14,075 tons of ore, 250 tons of which were siliceous gold ore of an average value of $2.09 per ton, and 13,825 tons were copper ores and pyrite cinder yielding 35 cents in precious metals and 16.2 pounds of copper per ton.

In 1910, the production of gold and silver in Virginia showed a marked decrease over that of 1909. The total production of gold was 42.96 fine ounces valued at $888, and of silver 128 fine ounces valued at $69.

There is given in the table below, compiled from the production reports of the United States Mint and Mineral Resources of the United States, the production of gold and silver in Virginia by years.

Production of Gold and Silver in Virginia by years.

Year	Value	Year	Value
1799–1879......	$3,091,700	1895...........	$ 6,325
1880...........	11,500	1896...........	4,466
1881...........	10,000	1897...........	Not given.
1882...........	15,000	1898...........	4,500
1883...........	7,000	1899...........	7,160
1884...........	2,500	1900...........	3,200
1885...........	3,500	1901...........	5,720
1886...........	4,000	1902...........	6,227
1887...........	14,600	1903...........	18,630
1888...........	7,500	1904...........	7,686
1889...........	4,113	1905...........	5,122
1890...........	6,496	1906...........	15,000
1891...........	6,699	1907...........	8,434
1892...........	5,002	1908...........	2,576
1893...........	6,190	1909...........	6,259
1894...........	7,643	1910...........	957

In the subjoined table are given the quantity and value of gold and silver produced in Virginia for the years 1906, 1907, 1908, 1909, and 1910.

Production of Gold and Silver in Virginia by years, 1906-1910.

Year	Gold		Silver	
	Quantity in fine ozs.	Value	Quantity in fine ozs.	Value
1906.....	717.50	$14,832	250	$168
1907.....	400.93	8,288	221	146
1908.....	118.57	2,451	236	125
1909.....	181.41	3,750	4,825	2,509
1910.....	42.96	888	128	69

COPPER.

Copper ores are found in many counties of the State and in a variety of occurrences. They are confined to the crystalline rocks of the Piedmont Plateau and the Blue Ridge Mountains, and to the Triassic red beds, which form numerous small areas in the Piedmont province:

The known geographic areas of these ores in the State are:

I. THE PIEDMONT REGION:
  (1) The Virgilina district, which includes Halifax and Charlotte counties in Virginia, and Person and Granville counties in North Carolina.
  (2) The deposits on or near Southwest Mountain in Albemarle County, and those near New Canton, Arvonia, and Dillwyn, in Buckingham County.
  (3) The pyrite bodies in Louisa, Stafford, and Prince William counties, mined principally for their sulphur content, but carry at times sufficient copper to warrant saving.

II. THE NORTHERN BLUE RIDGE REGION:
  Includes those deposits from near Front Royal southward, embracing parts of Warren, Fauquier, Rappahannock, Madison, Page, and Greene counties.

III. THE SOUTHWEST VIRGINIA REGION:
  Includes the "Gossan Leads" of the Floyd-Carroll-Grayson counties plateau.

IV. THE TRIASSIC AREAS:
  Includes deposits chiefly in Loudoun, Culpeper, and Orange counties.

Geologically, the copper ores are confined to the crystalline rocks, either the schists or gneisses or the massive igneous rocks of the Piedmont and Blue Ridge provinces, and to the red shale-sandstone series of the Triassic areas. In the Virgilina district, the ores occur in quartz-fissure veins which intersect or lie in an altered andesite and associated tuffs of probable pre-Cambrian age. The ores of the northern Blue Ridge region are segregated in and disseminated through basaltic flows of pre-Cambrian age, rocks designated by Keith as Catoctin schist. The "Great Gossan Lead" of the Floyd-Carroll-Grayson counties plateau, in southwest Virginia, is a mineralized faulted zone in schists of doubtful age, probably pre-Cambrian in part. The rocks are in part altered sediments and in part altered igneous masses of basic and acid types, principally the former.

The Virginia copper deposits may be grouped into five types:

(1) Pyrite masses in schistose rocks worked chiefly for their sulphur content, but containing enough copper in places to be saved. The well-known and extensively worked pyrite bodies near Mineral, in Louisa County, and near Dumfries, in Prince William County, are the best representatives of this type.

(2) Pyrrhotite veins containing chalcopyrite and some pyrite in schistose rocks referred to usually as the Ducktown, Tennessee, type, the most productive copper district in the South. The best representative of this type in Virginia is the "Great Gossan Lead" in Carroll County.

(3) The Virgilina type in Virginia and North Carolina which represents quartz-fissure veins carrying chalcocite (copper glance) and bornite (horseflesh ore), with little or no pyrite and chalcopyrite, in volcanic rocks of intermediate character and their associated tuffs.

(4) The northern Blue Ridge or Catoctin type, the ores of which are chiefly native copper and cuprite with small amounts of the carbonates, azurite and malachite, and very rarely copper sulphides associated with epidote and quartz in a basic volcanic rock, and as grains disseminated through the rock.

(5) The Triassic type, carbonate, representing sparsely disseminated copper ores, chiefly sulphide, and phosphate of copper, in sandstones and shales of Triassic age.

In addition to these five types, copper in the form of the mineral chalcopyrite is a frequent associate with gold in the gold-bearing quartz-pyrite veins in the principal gold belt of the Piedmont province. Copper has not been observed, however, at any locality within the State in this mode of occurrence to be regarded as of commercial value.

Mining operations for copper in the State have been confined principally to three districts; namely, the Virgilina district, the northern Blue Ridge district, and the "Great Gossan Lead" district. Isolated deposits, which do not properly fall within either of these three districts, have been exploited in a number of localities, confined almost exclusively to the Piedmont counties.

The Virgilina copper district is, commercially, the most important district in Virginia, and the systematic study and detailed mapping on a large scale of the district has been completed by the State Survey, and the report is nearly ready for the press. It is located 47 miles east of Danville on the Atlantic and Danville division of the Southern Railway, and includes a part of Halifax, Charlotte, and Mecklenburg counties.

The principal developments in the district, which include a large number of mines, are confined to an approximate north-south distance of eighteen miles, and an average width of from two to three miles. The present productive portion of the district has about equal extension in the two states, Virginia and North Carolina. The country rock is schist, derived principally from intermediate and acid volcanic rocks and their associated tuffs. The schistosity of the rock strikes N. 10° to 20° E. and dips eastward from 70° to 80°. The quartz veins, of which there are many, are usually more or less parallel, and strike N. 5° to 10° E., with considerable variations from this direction in places. Mining developments show that copper occurs in most of the veins in greater or less quantity. The veins are lenticular bodies of quartz which, in some cases, show very uniform continuous outcroppings at the surface. The workable ores comprise chalcocite or glance (copper sulphide) and bornite (copper-iron sulphide) in a siliceous gangue. Small masses of calcite and feldspar are occasionally noted as gangue minerals. Cuprite (copper oxide), malachite and azurite (green and blue carbonates of copper) occur as alterations of the original sulphides. Some native copper is noted in places. Chalcopyrite and pyrite are almost entirely absent. The worked ores are free from arsenic and antimony, but carry values in both silver and gold, particularly the former.

The "Great Gossan Lead" of Floyd, Carroll, and Grayson counties is a vein traceable for some eighteen miles. It is composed chiefly of pyrrhotite with admixed quartz and schist, and carries streaks and patches of chalcopyrite and pyrite. The vein fills a fault fracture in crystalline schists, varies in width from a few feet to one hundred feet, shows a somewhat variable but average dip of about 45°, and has in general an approximate northeast trend. The region was actively prospected in the early fifties, and the rich secondary copper ores found beneath the gossan were boxed and shipped to Baltimore. During 1854-5, there were eight producing mines on the "Gossan Lead"; the aggregate amount of ore shipped for the six months from January, 1855, to July, 1855, being 1,454,363 pounds. The ore averaged about 25 per cent copper. The copper content of the sulphide masses is too low (averaging less than 1 per cent metallic copper) to work for copper alone, but the vein is mined on Chestnut Ridge and the ore treated at Pulaski for sulphur, so that the residue is available for copper.

The northern Blue Ridge region, which extends from near Front Royal southward, embracing parts of six counties, has been extensively prospected, and many mines have been developed, but as yet with little production of the metal. The ores of the Blue Ridge region consist chiefly of cuprite and native copper, small amounts of green and blue carbonates, and less of the sulphides, bornite and chalcopyrite. The native copper often occurs as nucleal masses surrounded by cuprite. Bornite is in excess of chalcopyrite. The ore occurs along crevices and joints in small, irregular shaped lenses of quartz, and as disseminated grains through the more epidotized portions of the basalt. It occurs mostly where the rocks are fractured and epidotized. When ore-bearing, the rocks are yellowish green in color, due largely to the formation of epidote and, in part, of chlorite.

During the early part of the last century, attempts were made to mine the sparsely disseminated copper ores in the red sandstones and shales of Triassic age over parts of Loudoun, Culpeper, and Orange counties. While considerable work was done, the ores appear to be too generally diffused in the rocks to be of commercial value. No veins have been found and no well-defined horizons are known, the ores occurring for the most part as films or thin coatings of malachite on the joint surfaces, and as disseminated grains of the sulphide and phosphate of copper through the rocks. Rich specimens of copper glance and copper phosphate are sometimes obtained, but they are by no means abundant.

The production of copper in Virginia during 1909 was 224,162 pounds, valued at $29,141, as compared with 24,775 pounds in 1908, valued at $3,270, an increase of 199,387 pounds in quantity and $25,871 in value. The production in 1910 showed a marked decrease over that of 1909, amounting in total to 5,402 pounds in quantity, valued at $686.

LEAD AND ZINC.

Lead mining in Virginia dates back more than 150 years, and the old lead mines at Austinville on New River, in Wythe County, were the first to be worked. For many years after the Virginia mines were operated, mining was confined exclusively to the lead ores. Zinc ores were first discovered at Bertha near Austinville, in Wythe County, during the year 1876. Mining of zinc ores in Virginia dates from the opening of the mine at Bertha in 1879, when a small shipment of ore was made to Providence, Rhode Island. The metal obtained from these ores proved to be of such rare purity that attention was directed at once to them, and a smelting plant was built at Pulaski, which was later remodeled and enlarged, and is owned and operated at present by the Bertha Mineral Company. The "Bertha" spelter is of exceptional purity, and has a world-wide reputation.

Excepting the single deposit in the extreme southwestern part of Albemarle County, the known deposits of lead and zinc in Virginia are limited to the Valley province west of the Blue Ridge. All mining and prospecting for lead and zinc ores in this province have been confined to the western half, extending from and including Roanoke County on the east to and including Scott County on the southwest. Ores of lead and zinc are known to occur either sparingly or in quantity in the following counties: Roanoke, Montgomery, Pulaski, Wythe, Smyth, Bland, Tazewell, Russell, Scott, and Albemarle. Of this number, only one county, Wythe, has shown as yet producing mines. More or less prospecting has been attempted in the majority of the counties named above, and small amounts of the ore have been mined in a number of them.

Geologically, the occurrence of lead and zinc ores in southwest Virginia is limited to the magnesian limestone of Cambro-Ordovician age, known as the Shenandoah or Valley limestone. The known commercial deposits of these ores occur near the eastern side of the Valley, though several promising prospects are opened near the western side.

The ores include (1) the original sulphide forms sphalerite (sulphide of zinc), galenite (sulphide of lead), pyrite (sulphide of iron), and in several places chalcopyrite (the double sulphide of iron and copper); and (2) the secondary or oxidized forms which have been derived from the original sulphides and occur in the residual clays derived by weathering from the limestone. These include calamine (hydrous silicate of zinc), smithsonite (carbonate of zinc), and cerussite (carbonate of lead). Named in the order of their importance, dolomite, calcite, barite, fluorite, and quartz are the associated nonmetallic minerals.

The bulk of the sulphide ores belong to the disseminated replacement breccia type. Little or no replacement of the limestone by the ore is indicated in some places. The zones of breccia ore are associated with faulting and folding. Not all parts of the breccia zones are mineralized, but the ore is distributed at irregular intervals. The oxidized ores usually show much richness, and are often concentrated in massive form as large, irregular masses and layers, principally at and near the bottom of the residual clays, closely hugging the irregular weathered surface of the limestone. Until recently only the oxidized or secondary ores have been mined. These have been practically exhausted and attention is now directed to mining the original sulphide ores in the fresh limestone.

The ores are shipped to Pulaski, and smelted at the zinc smelting plant of the Bertha Mineral Company. Three grades of spelter are made, branded according to purity: "Bertha Pure Spelter," "Old Dominion," and "Southern."

The single deposit of lead and zinc ores in Albemarle County is the only type of its kind known in the South. The mine is owned by the Albemarle Zinc and Lead Company, and is located two miles slightly north of east from Faber. The associated rocks are metamorphic crystalline schists, cut by dikes of diorite and diabase. The metalliferous vein, traced for a distance of several miles, averages about four feet in width, strikes N. 45° E., and dips 80° to 85° northwest. Where opened, the vein is of the lenticular type, composed of bulbous bodies of fluorspar and some quartz through which the ore, blende and galena, is distributed. The ore is treated in an 80-ton mill erected at the mine.

The production of lead in Virginia in 1908 was 76,190 pounds, valued at $3,200. There was no production of lead or zinc reported from the Virginia mines in 1909. The production of zinc reported is to be credited to the reworking of old dumps. The 1910 production of lead amounted to 198,850 pounds, valued at $8,750.

The production of spelter in Virginia in 1906 was 1,143 short tons, valued at $139,446; in 1907, 771 short tons, valued at $90,978; in 1908, 910 short tons, valued at $85,540; in 1909, 58 short tons, valued at $6,298; and in 1910, 794+ short tons, valued at $85,758.

TIN.

Though not a producer of tin, the existence of tin ore in the Irish Creek area of Rockbridge County has been known for many years, and in 1883 and later the deposits were opened in several places. The Irish Creek area is about 4 miles long in a northeast-southwest direction and 3 miles wide, embracing a total area of 12 square miles. The immediate rocks of the area are of granitic composition, composed principally of a coarse aggregate of quartz and feldspar (orthoclase and albite), with hornblende, and in places some epidote. Dikes of fine-grained altered diabase cut the granitic rocks in all directions, and apparently are frequently associated with the tin-bearing veins.

The tin ore (cassiterite) occurs principally in greisen veins, which traverse the granite in all directions and have steep though varying dips. The veins are usually narrow, not exceeding a foot and less, though a greater thickness is frequent and some of the veins measure several feet across. The cassiterite is disseminated in small crystals and fine grains indistinguishable to the naked eye. The associated minerals comprise wolframite, mispickel (arsenopyrite), pyrite, and beryl. In addition to these, siderite, limonite, chlorite, muscovite, damourite, and fluorspar have been reported. The mispickel is reported by McCreath to contain both gold and silver.

NICKEL AND COBALT.

The existence of nickel in Virginia has been reported from a number of localities in the Piedmont region, especially in association with the extensive pyrrhotite bodies of the Floyd-Carroll-Grayson counties plateau in southwest Virginia, and in Amherst County east of Lynchburg. More recently nickel in association with peridotite masses has been reported from near Broadrun station in Fauquier County. In addition to the above occurrences, cobalt is found in association with some of the impure earthy manganese deposits of the Valley region, especially along the western base of the Blue Ridge.

Probably the most encouraging locality in the State from which nickel has been reported is in the northern part of Floyd County, where considerable exploratory work on Flat Run and Lick Fork has been carried on. The Lick Fork openings are the principal ones in the area, and the ore is chiefly pyrrhotite with some chalcopyrite. At the time of my visit in May, 1907, a large amount of ore on the dump was reported to average by actual assays not less than 1.75 per cent of nickel and a fraction of 1 per cent of copper. As much as 0.4 per cent of cobalt was reported, but the average is considerably less. Assays of the pyrite from other openings in the area are reported to yield from 3 to 4 per cent of nickel.

The rocks immediately associated with the ore are, without exception, of igneous origin, and comprise pyroxene syenite, diabase, and gabbro. These are intruded into the country schists and gneisses. The gabbro and diabase penetrate the pyroxene syenite in dike-like forms and are accordingly younger in age. The mica-gabbro is the ore-bearing rock. In some parts of the gabbro, the sulphides are sparingly present, in others they make up 50 per cent and more of the total rock mass, with all gradations between.

COAL.

The first coal mined in the United States was in the Richmond basin, where mines were opened and worked on the James River, near Richmond, as early as 1750. The production from the Richmond basin increased until 1832 (the production in 1828 being 100,280 tons), when it began to decline. In 1908, redevelopment of the mines at

Gayton by the Old Dominion Development Company was begun, and in 1910 a good production was reported by the company.

The construction of the Norfolk and Western Railway through southwest Virginia in 1882, opened up the famous Pocahontas coal district, which lies partly in Virginia. Likewise, the building of the Clinch Valley division of the Norfolk and Western Railway, nine years later, marked the beginning of the development of the Wise County coal district. The developments in these two fields in southwest Virginia, Tazewell County in 1883 and Wise County in 1891, restored Virginia to importance as a coal producer.

Coal was mined in the Montgomery-Pulaski counties area prior to the Civil War, but not in an extensive way. For a period of 30 years after the Civil War, the only mining carried on in this field was to supply a limited local market. Within recent years larger developments have been made, and until the beginning of the financial panic in the latter part of 1907, the production was correspondingly increased.

Coal is mined in two of the three major provinces of the State, namely, the Mountain province and the Piedmont province. Recent developments in the Piedmont province (Richmond coal basin) will undoubtedly restore this area again to the rank of an important producer.

The Virginia areas which have produced or are producing coal are as follows:

I. The coal deposits of the Piedmont province. Includes the Richmond Coal Basin, which covers parts of the following five counties: Henrico, Chesterfield, Powhatan, Goochland, and Amelia. This is the only area of free-burning coal in the eastern portion of the United States that is located immediately adjacent to tidewater. The Farmville area, which covers parts of Prince Edward, Cumberland, and Buckingham counties.

II. The coal deposits of the Mountain province, which include a number of separate areas extending across the State in a southwesterly direction from Frederick County on the north to the Tennessee boundary on the south.

(1) The Frederick County Area. Including the Mountain Falls district in the southwestern portion of the county and near the West Virginia line.

(2) The Augusta County Area. Includes the North River district in the northwest corner of Augusta County and the contiguous part of Rockingham County.

(3) The Botetourt County Area. Includes the southwest corner of Botetourt County.

(4) The Montgomery-Pulaski Counties Area. Includes Price and Brush mountains in Montgomery County, and Cloyd and Little Walker mountains in Pulaski County.

(5) The Bland-Wythe Counties Area. Includes a small area in the southern part of Bland County and in the northern part of Wythe County.

(6) The Southwest Virginia Area. Forms the southeastern portion of the Kanawha basin, and comprises the Pocahontas or Flat-Top and the Big Stone Gap coal fields of the following counties: Tazewell, Russell, Scott, Buchanan, Wise, and Lee.

Geologically, the Virginia coal deposits are grouped as (1) those of Triassic age, including the Richmond coal basin, and (2) those of Carboniferous age, which includes all coal deposits found west of the Blue Ridge. Of the Carboniferous coal deposits, those of the Mountain Falls district, in Frederick County, the North River area of Augusta County, the North Mountain area of Botetourt County, the Montgomery-Pulaski counties area, and the Bland-Wythe counties area are Mississippian (Lower Carboniferous) in age. The Virginia portion of the Appalachian coal field, which includes the extreme southwest counties along the border of West Virginia and Kentucky, and to which the State owes its rank as a coal producer, is Pennsylvanian (Upper Carboniferous) in age.

The southwest Virginia coal field forms the southwestern part of the Kanawha basin and comprises the following counties: Buchanan, Dickenson, Lee, Russell, Scott, Tazewell, and Wise. Of these, Wise, Tazewell, and Lee counties are the most important producers at present. The other counties contain large reserves of coal, which in places are rapidly undergoing development. This is especially true of Russell County, whose coal production increased more than 100 per cent in 1909. Many of these reserves have been made accessible recently through the construction of new lines of railroad, which means increased activity in coal mining in the State and a greater production in the immediate future.

It is due to the southwest Virginia fields that Virginia is entitled to rank among the principal coal-producing states. This area, the Virginia portion of the Appalachian coal field, is estimated to contain

1,550 square miles, with the original supply of coal placed at 22,500,000,000 short tons. Campbell and Parker state that from this there had been produced, at the close of 1907, a total of 57,229,152 short tons, representing an exhaustion of 86,000,000 tons. "The production in 1907 was 4,710,895 short tons, equivalent to an exhaustion of little over 7,000,000 tons, so that the coal left in the ground in Virginia at the close of 1907 was 2,000 times the exhaustion represented by the production of that year."

The Pocahontas and Big Stone Gap coal fields are the most extensively developed coal fields in the Virginia portion of the Appalachian region.

A goodly number of coal beds are found within the total vertical limits of the geological formations composing the Pocahontas field. Some of these are thin, but at least six workable beds have been opened in places. Not all of these are workable, however, at any one locality, and in places only one is worked. The superior quality of the Pocahontas coal has long established it as the best steam coal in the world. It produces an excellent coke, but, as a rule, the lump coal is placed directly upon the market for general purposes, while the slack and fine coal go direct to the ovens for coking.

The Big Stone Gap coal field in Virginia embraces parts of Lee, Scott, and Wise counties. Although opened up nearly ten years after the famous Pocahontas field, it is much the largest producer of coal and coke, and Wise County is the largest coal- and coke-producing county in the State. Wise County contributes at present about 60 per cent of the State's total coal production.

There are eight workable seams of coal in the district, ranging in thickness from 3.5 to 12 feet, included within a vertical distance of about 1,200 feet. Of these, the four highest have their greatest development in the western part of the district.

The coal mining industry in Virginia showed a marked increase during the years 1909 and 1910 over that of previous years. Virginia was one of the few states whose production in 1909 exceeded that of 1907, which was due to the increased production in Wise County and to active development in Russell County. The production in Wise County increased from 2,558,874 short tons in 1908 to 2,841,448 tons in 1909. Russell County's production increased more than 100 per cent. The production in Tazewell County was 4,349 tons less in 1909 than in 1908, and in Lee County 15,117 tons less in 1909. The total production in Virginia for 1909 amounted to 4,752,217 short tons, valued at $4,251,056, as compared with 4,259,042 short tons, valued at $3,868,524, in 1908. This represents an increase in quantity of 493,175 short tons, or 11.5 per cent, and in value of $382,502. The average price per ton was 89 cents in 1909 against 91 cents in 1908 and $1.02 in 1907. The number of mining machines increased from 85 in 1908 to 107 in 1909, and the machine-mined coal increased from 1,035,832 tons to 1,323,111 tons, nearly 30 per cent of the total quantity of coal mined in 1909. None of the Virginia coal is washed before being sold or used.

Virginia established a new record in her coal production in 1910. The production in Lee, Russell, Tazewell, and Wise counties showed a marked increase in 1910 over that of the previous year, due to the considerable development in progress, not so much in the way of new companies, but in the expansion of properties already developed. This is particularly true of Russell County. The reason for the increased production in 1910 over that of 1909 was indirectly the strike in the coal mines of Illinois and the southwestern States.

The production in Tazewell County increased from 975,665 short tons in 1909 to 1,187,146 short tons in 1910; in Wise County from 2,841,448 short tons in 1909 to 3,730,992 short tons in 1910; and in Lee County from 485,960 short tons in 1909 to 792,763 short tons in 1910. The total production of coal in Virginia during 1910 amounted to 6,507,997 short tons, valued at $5,877,486, representing an increase over the 1909 production of 1,755,780 short tons in quantity, and $1,626,430 in value. This is the largest tonnage of coal ever produced in Virginia during a single year. The average price per ton of coal in the State during 1910 was 90 cents as against 89 cents in 1909. The number of mining machines increased from 107 in 1909 to 142 in 1910, and the machine-mined coal increased from 1,323,111 short tons to 2,290,435 short tons, more than 35 per cent of the total quantity of coal mined in 1909.

The accompanying table gives the quantity and value of coal produced in Virginia from 1890 to 1910, inclusive.

Quantity and value of Coal produced in Virginia, 1890 to 1910, inclusive.

Year	Quantity (short tons)	Value
1890	784,011	
1891	736,399	
1892	675,205	
1893	820,339	
1894	1,299,083	
1895	1,368,324	
1896	1,254,723	$ 848,851
1897	1,528,302	1,021,918
1898	1,815,274	1,070,417
1899	2,105,791	1,304,241
1900	2,393,754	2,123,222
1901	2,725,873	2,353,989
1902	3,182,993	2,543,595
1903	3,451,307	3,302,149
1904	3,583,914	3,076,011
1905	4,275,271	3,777,325
1906	4,254,879	4,183,991
1907	4,710,895	4,807,533
1908	4,259,042	3,868,524
1909	4,752,217	4,251,056
1910	6,507,997	5,877,486

There is given in the table below the production of coal in Virginia from 1900 to 1910, by counties.

Coal Production of Virginia, 1900-1910, by counties, in short tons.

County	1900	1901	1902	1903	1904
Montgomery	9,814	11,177	12,786	20,288	....
Tazewell	970,866	776,568	723,753	840,195	871,720
Wise	1,363,570	1,918.693	2,422,417	2,563,285	2,359,661
Chesterfield	49,504	19,435	24,037[a]	18,084	2,100
Henrico					
Pulaski				9,255	177,133[b]
Russell	....	....	....	....	....
Lee	....	....	....	....	....
Small mines	....	....	....	200	300
Total	2,393,754	2,725.873	3,182,993	3,451,307	3,410,914
Total value	$2,123,222	$2,353,989	$2,543,595	$3,302,149	$3,302,149

Coal Production of Virginia, 1900-1910, by counties, in short tons.—Continued.

1905	1906	1907	1908	1909	1910
....	....	....	6,022	(d)	(d)
961,380	910,638	1,116,534	980,014	975,665	1,187,146
2.990.698	3,041,225	3,145,846	2,558.874	2,841,448	3,730,992
....	....	....	....	....	....
....	....	....	....	....	(d)
323,073[c]	302,896[c]	448,515[c]	249,671	(d)	(d)
....	....	....	....	(d)	(d)
....	....	....	464,261	449,144	797.096
120	....	....	200	485,960[e]	792,763[f]
4,275.271	4,254,879	4,710.895	4,259,042	4,752.217	6,507.997
$3,777,325	$4,183,991	$4,807,533	$3,868,524	$4,251,056	$5,877.486

[a] Includes Chesterfield and Pulaski counties.

[b] Includes Montgomery County.

[c] Includes Lee and Montgomery counties.

[d] Included under "Small mines."

[e] Includes Montgomery, Pulaski, and Russell counties.

[f] Includes Montgomery, Henrico, Pulaski, and Russell counties.

LIST OF COAL OPERATORS

OPERATOR	OFFICE	MINE
American-Pocahontas Coal Co	Washington, D. C	American-Pocahontas
Barrowman Coal Co	Banner	Spruce Pine
Beacham Coal Co	Christiansburg	Beacham
Belle Hampton Coal Mining Co	Binghampton, N. Y	Belle Hampton
Big Vein Pocahontas Coal Co	Baltimore, Md	Big Vein Nos. 1 & 2
Black Mountain Collieries Co., Inc	Pennington Gap	Black Mountain No. 1
Black Mountain Mining Co	Big Stone Gap	Black Mountain
Blackwood Coal & Coke Co	Blackwood	Blackwood and Roaring Fork
Bond Coal Co	Tacoma	Greeno
Bondurant Coal & Coke Co	Pennington Gap	Bondurant
Browning, James S	Pocahontas	Browning
Bruce Coal & Coke Co	Tacoma	Bruce
Buchanan Coal & Coke Co	Richmond	Prospect
Catawba Mining & Mfg. Co	Roanoke	
Chesterfield Coal Co	Winterpock	Clover Hill
Clinchfield Coal Corporation	Dante and Johnson City, Tenn.	Cranes Nest
Clinch River Coal Co	Richlands	Clinch River
Clinch Valley Lumber Co	St. Paul	
Colonial Coal & Coke Co	Dorchester	Dorchester
Darby Coal & Coke Co	Cincinnati, Ohio	Darby
Dickenson, W. E	Coeburn	
Dixie Coal & Coke Co	Raven	Dixie
Domestic Coal Co	Raven	Domestic
Dominion Coal Co	Pennington Gap	Blanche, Early, Mabel Edgar, and Susie Ferge
Empire Coal Land Corporation	Alfredton	Seaboard
Esser Coal & Coke Co	Esserville	Esserville

OPERATOR	OFFICE	MINE
Fleming & Co., Robert	Norton	Banner
Goodloe Bros. Co., Inc	Big Stone Gap	Pin Hook
Hale, J. E	Wise	
Huettel Coal & Coke Co	Norton	Huettel
Hyndman Coal & Coke Co	Norton	Carlson
Imboden Coal & Coke Co	Imboden	Imboden
Intermont Coal & Iron Co. (Kelly & Irvine)	Big Stone Gap	Josephine
James River Coal Corporation	Midlothian	Midlothian
Jewell Ridge Coal Co	Tazewell	Jewell Ridge
Keokee Consolidated Coke Co	New York, N. Y	Imboden, Keokee
Kinzer & Son	Vicar Switch	Stroubles Creek
Lee Coal Co	Middlesboro, Ky	Lee
Lick Branch Anthracite Coal Co	Christiansburg	
Litz, J. L	Coeburn	
Monarch Coal Co., Inc	Cincinnati, Ohio	Leona
Norton Coal Co	Norton	Norton, Nos. 1, 2, and 3
Old Dominion Development Co	Richmond	Carbon Hill
Pennington Coal Co., Inc	Pennington Gap	Pennington
Pocahontas Consolidated Collieries Co	Pocahontas	Boissevain and Pocahontas
Pocahontas Mining Corporation	Tazewell	Big Creek
Pound River Coal Corporation	Wise	Pound River
Price Bros	Cambria	Blacksburg Mng. & Mfg. Co.
Price Mountain Coal Co. (Bandy, Warren & Hawser)	Roanoke	Myers
Pulaski Anthracite Coal Co	New York, N. Y	Parrott
Raven Collieries Co	Raven	Coal Creek
Raven Fuel Co	Raven	Red Ash
Raven Red Ash Coal Co	Red Ash	Red Ash
Richlands Coal Co	Richlands	Richlands
St. Paul Coal & Coke Co	St. Paul	St. Paul
Scott County Mineral Co	Bristol, Tenn	
Slusser & Co., M. C	Blacksburg	Brush Mountain
Smith & Co., H. P	Blacksburg	Snider Hill
Southern Anthracite Coal Co	Roanoke	Clear Air
Southern Pocahontas Coal Co	Richlands	Sater
Stonega Coke & Coal Co	Big Stone Gap	Arno, Nos. 1 and 2; Crossbrook, Osaka; Roda, and Stonega
Stonegap Colliery Co	Glamorgan	Glamorgan
Sutherland Coal & Coke Co	Dorchester	Sutherland
Tacoma Coal & Coke Co	Tacoma	Tacoma
Town Hill Coal Co., W. R. Williams	Bramwell, W. Va	Town Hill
Trigg & Kent	Bristol, Tenn	T. & K.
Virginia Anthracite Coal Co	Richmond	Merrimac
Virginia City Collieries Co	Virginia City	Virginia City
Virginia Iron, Coal & Coke Co	Roanoke	Coeburn, Inman, Lee, Linden, Looney Creek, Marion, Pine Run, Swansea, Sexton, and Thelma
Virginia Lee Co., Inc	Pennington Gap	St. Charles and Virginia Lee
Virginia-Tennessee Coal Co	Knoxville, Tenn	Coal Creek
Wise Coal & Coke Co	Dorchester	Wise
Yellow Creek Coal & Coke Co., Inc	Wise	Yellow Creek

COKE.

The coking coals of Virginia are confined to a few counties in the extreme southwestern portion of the State. The rapid development of the coking-coal fields in this portion of the State during the last few years has given Virginia rank as one of the four principal coke-producing states. Prior to 1895, there were only two coke-making establishments in Virginia, with a production of less than 200,000 tons per year. The number of establishments increased to seven in 1901, and the total number of coke ovens increased from 832 in 1896, to 2,775 in 1901, with a total production of more than 900,000 short tons. Construction and development work progressed rapidly during 1902, the number of establishments was doubled, and, at the close of the year, 2,974 ovens were built and 1,208 were building, with the production increased 1,124,572 short tons.

In 1903, two more establishments were added, making the total number 16, with a total of 4,251 ovens, and the production further increased to 1,176,439 short tons. In 1904, there was an increase of 94 completed ovens, the number of establishments remaining the same as in 1903, while the production declined to 1,101,716 short tons. Two establishments having a total of 107 ovens were reported idle during the year 1904. One of these was the Newton-Chambers ovens at Pocahontas in Tazewell County.

The production of coke in 1905 amounted to 1,499,481 short tons, valued at $2,869,452, as compared with 1,101,716 short tons, valued at $1,772,717 in 1904, an increase of 36.1 per cent in quantity, and 62 per cent in value. The number of ovens increased from 4,345 in 1904 to 4,549 in 1905, an increase of 204.

There were 18 establishments in 1906, an increase of two over 1905, and the total number of ovens increased from 4,549 to 4,641 in 1906. The production increased from 1,499,481 short tons in 1905, valued at $2,869,452, to 1,577,659 short tons, valued at $3,611,659. The value of coke at the ovens increased from $1.91 per ton to $2.29.

In 1907, the production of coke decreased from 1,577,659 short tons in 1906, to 1,545,280, a loss of 32,379 tons, or 2.1 per cent. Owing, however, to better prices which prevailed in 1907, the value of the coke produced increased from $3,611,659 in 1906 to $3,765,733 in 1907, an increase of $154,074, or 4.3 per cent. There were 19 establishments in 1907, an increase of one over 1906, and the number of ovens increased from 4,641 to 5,333 in 1907.

The monetary troubles in the latter part of 1907 very seriously effected the coke industry in the State during 1908. There was a decrease in the amount of coke from 1,545,280 short tons in 1907 to 1,162,051 tons in 1908, a loss of 383,229 tons, or 24.8 per cent; and, in value, a decrease from $3,765,733 in 1907 to $2,121,980 in 1908, a loss of $1,643,753, or 43.65 per cent. The value of coke at the ovens decreased from $2.44 per ton in 1907 to $1.83 in 1908. The number of establishments (19) remained the same as for 1907, but there was a decrease in ovens from 5,333 to 4,853 in 1908.

The production of coke in Virginia during 1909 was 1,347,478 short tons, valued at $2,415,769, which represented an increase over the production for the previous year, of 185,427 tons in quantity and $293,789 in value. The number of ovens reported in existence was 5,469; number building, 100. The value of coke per ton was $1.79 as compared with $1.83, the value per ton in 1908.

The production of coke in Virginia during 1910 was 1,493,655 short tons, valued at $2,731,348, which represented an increase over the production for 1909 of 146,177 tons, or 10.9 per cent, and $315,579, or 13.1 per cent, in value. The number of establishments was reduced from 19 to 18 and the number of ovens from 5,469 to 5,389. There were 100 beehive ovens in course of construction at the close of 1910. The value of coke per ton increased from $1.79 in 1909 to $1.83 in 1910.

The principal part of the coke production in Virginia during the last few years has been from the development of the coal fields in Wise County, on the Clinch Valley division of the Norfolk and Western Railway. During 1906 and 1907 extensive developments were made in the Black Mountain field in Lee County following the construction of the Black Mountain railroad. The first ovens in Lee County were reported under construction in 1907, with an output in 1908 of 50,000 tons, which was increased to over 100,000 tons in 1909, but decreased to 86,000 tons in 1910. The production in other districts increased during 1910, and the total output for the State showed an increase of 146,177 tons, or 10.9 per cent, and in value of $315,579, or 13.1 per cent. The average price per ton advanced from $1.79 in 1909 to $1.83 in 1910. The coal for the plant at Lowmoor and the one at Covington is drawn from the mines in the New River district of West Virginia, and that for the ovens at Pocahontas in Tazewell County is obtained from mines extending across the State boundary into West Virginia.

Of the 1910 production of coke in Virginia, 1,025,144 short tons of the total tonnage (1,493,655) came from Wise County. The value of the production from Wise County was $1,883,344. In order to avoid disclosing individual figures, it is not possible to publish the production of the other counties producing in 1910. These counties, however, listed in order of productions were: Roanoke, Tazewell, and Alleghany.

In the subjoined table are shown the statistics of the manufacture of coke in Virginia in 1883, when the first operations were begun, in 1890, 1900, and from 1903 to 1910, inclusive.

Statistics of the manufacture of Coke in Virginia, 1883-1910.

Year	Establishments	Ovens		Coal used (short tons)	Coke produced (short tons)	Total value of coke at ovens
		Built	Building			
1883	1	200	0	39,000	25,340	$ 44,345
1890	2	550	250	251,683	165,847	278,724
1900	7	[a]2,331	300	1,083,827	685,156	1,464,556
1903	16	[a]4,251	142	1,860,225	1,176,439	2,724,047
1904	16	[a]4,345	68	1,636,905	1,101,716	1,772,717
1905	16	[a]4,549	0	2,184,369	1,499,481	2,869,452
1906	18	[a]4,641	695	2,296,227	1,577,659	3,611,659
1907	19	[a]5,333	50	2,264,720	1,545,280	3,765,733
1908	19	4,853	158	1,785,281	1,162,051	2,121,980
1909	19	5,469	100	2,060,518	1,347,478	2,415,769
1910	18	[a]5,389	100	2,310,742	1,493,655	2,731,348

[a] Includes 56 Newton-Chambers by-products ovens.

All the coal used in coke-making in Virginia up to 1895 was unwashed. Washing of slack coal began in 1896, and in 1898 the amount of washed slack coal used amounted to 210,000 short tons. All the coal used in the manufacture of coke in the State during the years 1909 and 1910 was unwashed. Of the 2,310,742 short tons of coal made into coke during 1910, 1,554,784 tons were run-of-mine and 755,958 tons were slack.

The character of the coal used in coke-making in Virginia during 1890, 1900, and from 1903 to 1910, inclusive, is shown in the table below.

Character of Coal used in the manufacture of Coke in Virginia, 1890-1910, in short tons.

Year	Run-of-Mine		Slack		Total
	Unwashed	Washed	Unwashed	Washed	
1890	98,215	0	153,468	0	251,683
1900	620,207	0	463,620	0	1,083,827
1903	857,332	0	1,002,893	0	1,860,225
1904	1,213,226	44,222	379,457	0	1,636,905
1905	1,096,656	0	1,087,713	0	2,184,369
1906	1,014,299	228,347	1,053,581	0	2,296,227
1907	1,271,518	0	993,202	0	2,264,720
1908	1,438,754	0	346,527	0	1,785,281
1909	1,405,111	0	655,407	0	2,060,518
1910	1,554,784	0	755,958	0	2,310,742

LIST OF COKE OPERATORS

OPERATOR	OFFICE	MINE
Blackwood Coal & Coke Co..............	Blackwood	Blackwood
Colonial Coal & Coke Co................	Dorchester	Dorchester
Empire Coal Land Corporation............	Alfredton	Alfredton
Esser Coal & Coke Co....................	Esserville	Norton
Hyndman Coal & Coke Co................	Norton	Hyndman
Imboden Coal & Coke Co................	Imboden	Imboden
Intermont Coal & Iron Co................	Big Stone Gap........	Near Norton
Keokee Consolidated Coke Co............	New York, N. Y.......	Imboden and Keokee
Lowmoor Iron Co. of Virginia...........	Lowmoor	Covington and Lowmoor
Norton Coal Co.........................	Norton	Norton
Pocahontas Consolidated Collieries Co......	Pocahontas	Pocahontas
Stonega Coke & Coal Co..................	Stonega, Osaka, and Philadelphia, Pa.	Imboden, Osaka, and Stonega
Stonegap Colliery Co....................	Glamorgan	Glamorgan
Sutherland Coal & Coke Co..............	Dorchester	Manning
Virginia Iron, Coal & Coke Co............	Roanoke	Toms Creek and Inman
Wise Coal & Coke Co....................	Dorchester	Dorchester

CLAYS AND CLAY PRODUCTS.

Virginia contains a variety of clays widely distributed and occurring at various geological horizons. They are found abundantly distributed throughout the Coastal Plain, Crystalline, and Mountain provinces of the State, and are adapted to a wide range of uses. Many of the deposits remain undeveloped, because they have not yet been investigated, and little is known regarding them. The only ones which have been systematically studied are those of the Coastal Plain or Tidewater region.

The clays of Virginia are suitable for many economic purposes, and can be divided into two groups, namely, residual and sedimentary. The residual clays have been formed by the weathering of rocks, involving processes of disintegration and decomposition. As a result of this, we find the residual clays overlying the parent rocks from which they were derived, forming deposits of variable thickness, depending partly on the depth to which the rocks have been changed, and partly on the amount of erosion they have suffered since their formation. Residual clays predominate in the belt (Piedmont region) underlain by the crystalline rocks, such as granites, gneisses, schists, etc., and have wide distribution west of the Blue Ridge. They are usually quite ferruginous and, therefore, red-burning. Their main use is for the manufacture of brick and drain tile, and some of the smoother deposits have been employed for making smoking pipes, notably those of Powhatan County.

The decomposition of pegmatite dikes in many of the Piedmont counties has yielded clays of high grade, free from iron, and sometimes sufficiently white to be used for the manufacture of white-ware products. Deposits of this type, known as kaolin, have been found in Amherst, Campbell, Hanover, Henry, Mecklenburg, Nelson, Patrick, and other counties in the Piedmont region.

The sedimentary clays represent deposits which have been laid down under water, one layer on another, the materials composing them consisting of the products of rock decay, which have been removed by erosion from the land surface, and washed down into the lakes or seas, where they have finally settled. These are abundant in both the

Coastal Plain province, where they are usually of unconsolidated character, and west of the Blue Ridge, in which region they are largely of a hard and shaly nature. They have wide distribution both geologically and geographically.

The Coastal Plain clays that have proved to be of marked value to the clay worker, occur in Eocene and Miocene beds of the Tertiary, and the Pleistocene of the Quaternary. The Eocene clays are best developed in the region south of Stafford Courthouse, where they form promising outcrops, but have not yet been developed. The Miocene clays are best known south of Richmond, in the vicinity of Curle's Neck, and Bermuda Hundred. This same formation also carries extensive beds of diatomaceous earth or clay, which is well exposed at Richmond and along the Rappahannock River. The Pleistocene clays occur as more or less basin-shaped deposits, widely scattered over the Coastal Plain region, and rest on top of the other formations.

Nearly all of the clay deposits noted in the Coastal Plain region, whatever their geological age, are of lenticular or lens-shaped character. The majority of them are red-burning, while only a few are buff-burning. No white-burning clays have thus far been found; but even though they lack in variety, so far as their color-burning qualities are concerned, it is probable that their possible uses are more numerous than is now supposed. Physical tests and chemical analyses of the clays in Tidewater Virginia are given in Bulletin I-A of the Virginia Geological Survey.

West of the Blue Ridge, in the Mountain province, shales probably suitable for brick-making have wide distribution, ranging in age from Cambro-Ordovician to Carboniferous. Many of these shale deposits will doubtless prove available for the manufacture of vitrified brick.

The abundant deposits of Virginia clays are only partially utilized at present, but, after their thorough investigation by the State Geological Survey and their uses better made known, they will be much more extensively employed and the industry greatly enlarged or expanded.

In 1909, the total value of all clay products manufactured in Virginia, including the value of kaolin, pottery products, fire clay, and miscellaneous clay mined and sold in the State, amounted to

$1,957,367. Compared with the value ($1,540,157) of the 1908 production, there was an increase of $417,210 or nearly 27 per cent.

In 1910, the total value of all clay products manufactured in Virginia was $1,841,731, a decrease from that of 1909 of $115,636.

The following table gives the statistics of clay products in Virginia from 1905 to 1910, inclusive, and is of interest to those who desire to know something of the growth of the industry in the State. The item "Miscellaneous" in the table includes all products not otherwise specified (fire brick, sewer pipe, drain tile, fancy or ornamental brick, kaolin, and pottery products), and those which could not be published separately without disclosing individual returns.

Clay Products in Virginia from 1905 to 1910, inclusive.

Product	1905	1906	1907
Brick:			
Common—			
Quantity	237,161,000	232,697,000	197,052,000
Value	$1,572,442.00	$1,536,312.00	$1,285,374.00
Average per thousand	$6.63	$6.60	$6.52
Vitrified—			
Quantity	(a)	....	....
Value	(a)	....	....
Average per thousand	$10.00	....	....
Front—			
Quantity	22,155,000	25,385,000	19,989,000
Value	$352,297.00	$392,130.00	$290,411.00
Average per thousand	$15.90	$15.45	$14.53
Fancy or ornamental. Value	$20,363.00	(a)	(a)
Fire. Value	(a)	$21,110.00	(a)
Drain tile. Value	$4,500.00	$4,805.00	$6,250.00
Sewer pipe. Value	....	....	....
Pottery:			
Earthenware and stoneware. Value	....	....	....
Porcelain electrical supplies. Value	(b)	(b)	(b)
Miscellaneous. Value	$44,976.00	$11,721.00	$29,300.00
Total value	$1,994,578.00	$1,966,078.00	$1,611,335.00
Number of operating firms reporting	94	91	87

[a] Included in miscellaneous.

[b] The value of pottery products for Virginia from 1905 to 1910, inclusive, is included under miscellaneous.

Clay Products in Virginia from 1905 to 1910, inclusive.—Continued.

Product	1908	1909	1910
Brick:			
Common—			
Quantity	185,738,000	249,794,000	229,982,000
Value	$1,219,946.00	$1,540,648.00	$1,460,460.00
Average per thousand	$6.57	$6.13	$6.35
Vitrified—			
Quantity	....	....	....
Value	....	....	....
Average per thousand	....	....	....
Front—			
Quantity	17,858,000	24,717,000	20,813,000
Value	$246,623.00	$333,057.00	$294,348.00
Average per thousand	$13.81	$13.48	$14.14
Fancy or ornamental. Value	(a)	(a)	(a)
Fire. Value	(a)	(a)	(a)
Drain tile. Value	$7,100.00	$6,298.00	$5,276.00
Sewer pipe. Value	....	(a)	(a)
Pottery:			
Earthenware and stoneware. Value	....	....	....
Porcelain electrical supplies. Value	(b)	(b)	(b)
Miscellaneous. Value	$66,488.00	$77,364.00	$81,647.00
Total value	$1,540,157.00	$1,957,367.00	$1,841,731.00
Number of operating firms reporting	82	89	87

[a] Included in miscellaneous.

[b] The value of pottery products for Virginia from 1905 to 1910, inclusive, is included under miscellaneous.

BRICK CLAYS.

Clays suitable for the manufacture of common and front brick, particularly the former, are widely distributed throughout the State. In fact, nearly every county in Virginia contains clay suitable for the manufacture of common brick, and, in most cases, the deposits are of such character that common brick of the best quality can be made. The brick-yards can be located usually near railroad transportation, and fuel for burning the brick can be obtained, as a rule, at a minimum price. Virginia clays used in the manufacture of common brick are of two types, residual and sedimentary, discussed on page 50.

The total number of common and front brick manufactured in Virginia in 1909 was 274,511,000, valued at $1,873,705, as against 203,596,000, valued at $1,466,569 in 1908, an increase of 70,915,000 in quantity and $407,136,000 in value. Of the 1909 production, 249,794,000 were common brick, valued at $1,540,648, and 24,717,000 front brick, valued at $333,057. The average value per thousand of the 1909 production was: Common brick, $6.13, front brick, $13.48.

During 1910, the total number of common and front brick manufactured in Virginia was 250,795,000, valued at $1,754,808, as against 274,511,000, valued at $1,873,705 in 1909, a decrease of 23,716,000 in quantity, and $118,897 in value. Of the 1910 production, 229,982,000 were common brick, valued at $1,460,460, and 20,813,000 front brick, valued at $294,348. The average value per thousand of the 1910 production was: Common brick $6.35, front brick $14.14.

The total value of fancy or ornamental brick and of fire brick produced in Virginia in 1909 was $30,984, and in 1910, $24,186. The quantity and value of the different varieties of brick manufactured in Virginia during 1909 and 1910 are given in the tables below.

In the tables below are given the total number and value of common and front brick manufactured in Virginia in 1909 and 1910, by counties.

Production of Common and Front Brick in Virginia in 1909, by counties.

County	Common Brick		Front Brick	
	Quantity (Thousands)	Value	Quantity (Thousands)	Value
Alexandria	75,874	$ 462,137	24,265	$ 327,083
Augusta	1,120	9,600		
Chesterfield	15,790	102,231		
Fairfax	9,125	57,584		
Henrico	31,728	201,600		
Nansemond	16,692	97,718		
Roanoke	15,019	94,687		
Rockingham	2,650	17,500		
Other counties	81,796[a]	497,591[a]	452[b]	5,974[b]
	249,794	$1,540,648	24,717	$333,057

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[a] Includes Albemarle, Alleghany, Brunswick, Campbell, Carroll, Charles City, Charlotte, Culpeper, Frederick, Grayson, Greenesville, Halifax, Henry, Isle of Wight. King George, Lancaster, Lee, Lunenburg, Montgomery, Norfolk, Nottoway, Orange, Pittsylvania, Prince George, Princess Anne, Rockbridge, Russell, Scott, Shenandoah, Spottsylvania, Sussex, Tazewell, and Warwick.

[b] Includes Halifax, Henrico, and Rockingham.

Production of Common and Front Brick in Virginia in 1910, by counties.

County	Common Brick		Front Brick	
	Quantity (Thousands)	Value	Quantity (Thousands)	Value
Alexandria	65,484	$ 415.551		
Augusta	925	7,300		
Chesterfield	9,115	60,644		
Fairfax	7,595	60,100		
Henrico	20,763	141,844		
Nansemond	16,771	99,545		
Roanoke Rockingham	17,300	104,600		
Other counties	92,029[a]	570.876	20,813[b]	$294,348
	229,982	$1,460,460	20,813	$294,348

[a] Includes Albemarle, Alleghany, Amherst, Brunswick, Campbell, Caroline, Carroll, Charles City, Charlotte, Culpeper, Frederick, Grayson, Halifax, Henry, Isle of Wight, James City, King George, Lancaster, Montgomery, Norfolk, Nottoway, Orange, Pittsylvania, Princess Anne, Powhatan, Rockbridge, Russell, Scott, Shenandoah, Smyth, Spottsylvania, Sussex, Tazewell, and Warwick.

[b] Includes Alexandria, Halifax, Henrico, James City, Pittsylvania, and Powhatan.

FIRE CLAYS.

Refractory clays are known to occur in many localities of the State, but they have not yet been investigated, and the production is small and variable. It is highly probable that the clayey members, including shales of the Carboniferous system of rocks, occurring west of the Blue Ridge and having the most extensive development in southwest Virginia, will prove of sufficient value for making vitrified wares. The Triassic shales associated with the coals of the Richmond basin have not proved of any value for the manufacture of clay products. Clays of the refractory type occur in a number of the Piedmont counties, and have been worked at several localities in some of these.

The production of fire clay during 1909 and 1910 was small and is included under "Miscellaneous" in the table on page 53.

POTTERY CLAYS.

The pottery industry in Virginia is a small one. The total value of pottery products made in Virginia in 1909 amounted to $36,746, as against $37,777 in 1908. This represents a decrease of $1,031. The value of pottery products made in the State during 1910 is included under "Miscellaneous" in the table on page 53.

KAOLIN.

The production of kaolin in Virginia has been derived almost entirely from the decomposed pegmatite dikes, which intersect the crystalline rocks of the Piedmont region. Deposits of this type have been worked in Amelia, Henry, and Nelson counties, and are known to occur but not developed in many other of the Piedmont counties. Of these, Henry is the principal producing county at present.

The production of kaolin in Virginia is small, and is included under "Other products" in the tables on pages 5 and 6, showing the mineral production in Virginia for the years 1909 and 1910.

LIST OF CLAY OPERATORS

BRICK AND TILE

OPERATOR	OFFICE	WORKS
Adams Bros. Co., Inc.	Bristol	Bristol
Adams Bros.-Paynes Co., Lynchburg Brick Works, Props	Lynchburg	Deacon
Alleghany Brick Co., Inc.	Covington	Covington
Altavista Brick Co., Inc. (Formerly Frazier Lbr. Co.)	Altavista	Altavista
Baltimore Brick Co.	Richmond	Rocketts
Barr, E. M.	Winchester	Winchester
Bell Bros	Strasburg	Strasburg
Billhimer, W. H.	Harrisonburg	Harrisonburg
Blackburn & Lohr	Staunton	Staunton
Bolling, Thomas A.	Farmville	Farmville
Booker Brick Co.	Newport News	Morrison
Boston Brick Co.	Houston	Houston and South Boston
Brister, C. M.	Petersburg	Ettricks (near)
Brooks & Son, A. M.	New River	Radford
Bromilaw Brick Co.	Alexandria	Hunting Creek
Buck & Co., Levin T.	Weems	Weems
Burroughs & Mankin, Inc.	Richmond	Manbur
Butler, Geo. W.	Culpeper	Culpeper
Capital Brick & Tile Corporation	Washington, D. C.	Alexandria
Champe, John A.	Lexington	Lexington
Charlottesville Brick Co.	Charlottesville	Charlottesville

OPERATOR	OFFICE	WORKS
Cheatwood & Blunt	Richmond	Brook Road
Clarke & Covington	Culpeper	Elkwood
Clark & Crupper	Washington, D. C.	Arlington
Cole & Son, W. C. (Formerly Galax Brick Co.)	Galax	Galax
Cooley Bros., Smith & Co	Marion	Marion
Copping, H. B	Chase City	Chase City
Corlon, W. H	Manchester	Manchester
Covington Brick Co. (Formerly Isaac Clark)	Covington	Covington
Coyner, J. M	Basic City	Basic City
Croghan, Daniel	Staunton	Staunton
Croushorn, B. G., Lessee of H. V. Croushorn, Prop	Weyers Cave	Weyers Cave
Crowell W. H	Bristol	Bristol
Cuthbert Land & Development Co	Wiehle	Wiehle
Davis Brick Co., Inc., W. Benjamin	Richmond	Manchester
Dickinson Fire Brick Co	Buena Vista	Buena Vista
Eureka Brick Co	Norfolk	Lynnhaven
Face & Son, E. W	Norfolk	Norfolk
Fellers Stone Co., Inc	Roanoke	Roanoke
Fitzgerald, N. A. & T. J	Danville	Danville
Ford & Wells	Lynchburg	Lynchburg
Franklin Brick Co	Franklin	Franklin
Frazier, W. R	Suffolk	Suffolk
Fredericksburg Brick Works	Fredericksburg	Fredericksburg
Fulton Brick Works	Richmond	Richmond
Gardner, John W	Mt. Airy, N. C	Woodlawn
Gilmore, W. J	Louisa	Lousia
Grinder, E. M	Washington, D. C	Rosslyn
Haden, George P. (Formerly B. D. Linney)	Blackstone	Blackstone
Hambrick, S. G	Lebanon	Barnett
Harrison Construction Co	Petersburg	Petersburg
Hatcher & Gaither	Orange	Orange
Hicks Brick Co	Lawrenceville	Lawrenceville
Hoffman, Geo. E	Culpeper	Culpeper
Holdaway, R. L. (Formerly W. E. Sutherland)	Major	Bridle Creek
Hoshour & Son, John S	Woodstock	Woodstock and Front Royal
Hoskins, D. W	South Boston	South Boston
Huffman & Son, J. S	Buena Vista	Buena Vista
Hurley, S. R	Grundy	Grundy
Hydraulic-Press Brick Co	Washington, D. C	Waterloo
Johnson, W. C	Spencer	Johnson's Siding
Jones, W. L	Williamsburg	James City
Keeler & Son, G. B	Petersburg	Broadway
Kenbridge Brick Co	Kenbridge	Kenbridge
Lawrenceville Brick & Tile Co., Inc	Norfolk	Lawrenceville
Layfield, F. G. (Formerly Oldfield Brick & Tile Co., Inc.)	Oldfield	Oldfield
Lemley & Sons, L. F	Strasburg	Strasburg
Lunenburg Brick & Tile Co	Kenbridge	Kenbridge
Mayo & Sons, W. R	Norfolk	Sturgeon Point
Moistproof Pressed Brick Co	Norfolk	Norfolk
Montgomery Brick Co	Christiansburg	Christiansburg

OPERATOR	OFFICE	WORKS
Mulberry Island Brick Co	Newport News	Mulberry Island
Musser & Son, W. H	Abingdon	Emory
Myers, Jacob S	Harrisonburg	Harrisonburg
Nalle, Orville	Elkwood	Elkwood
Nansemond River Brick & Tile Co	Norfolk	Reid's Ferry
New Washington Brick Co	Washington, D. C	Abingdon
Norton Brick Co	Norton	Norton
Oyster Point Brick Co	Oyster Point	Oyster Point
Patuxent Brick Co	Washington, D. C	Alexandria
Payne & Spindler	Drakes Branch	Drakes Branch
Phillips & Bro., C. H	Hampton	Hampton
Pierpont Brick Works	Salem	Pierpont Siding
Potomac Brick Co	Washington, D. C	Addison
Potomac River Clay Works	Takoma Park, D. C	Alexandria
Potts Estate, E. H	Chase City	Chase City
Powers Bros. & Maynard	Richmond	Richmond
Powhatan Clay Manufacturing Co	Richmond	Clayville
Radford Brick Co	Philadelphia, Pa	Tiptop
Rea, B. A. (Formerly Jno, W. Legg)	Stevensburg	Stevensburg
Ready, W. J	Manchester	Manchester and Henrico
Redford, N. C	Richmond	Manchester
Reynolds, R. C. (Formerly T. G. Layfield)	Oldfield	Oldfield
Richardson & Son, R. H	Hampton	Diascond
Richlands Brick Corporation	Norton	Richlands
Roanoke Brick Co. (Adams, Payne & Gleaves, Inc., Prop.)	Roanoke	Roanoke
Roanoke Clay Manufacturing Co	Roanoke	Webster
Rosslyn Brick Co	Washington, D. C	Rosslyn
Rosslyn Clay Material Co., Inc	Rosslyn	Rosslyn
Saint Paul Normal & Industrial School	Lawrenceville	Lawrenceville
Seale & Co., C. M	Rose Hill	Lennie
Shrum Bros	Dayton	Dayton and Harrisonburg
Southern Brick Co. (Formerly Geo. J. Fletcher)	Fredericksburg	Fredericksburg
Southern Clay Manufacturing Co	Chattanooga, Tenn	Chilhowie
Southern State Hospital	Marion	Marion
Southside Brick Co	Fredericksburg	Fredericksburg
Standard Brick Co., Reed Bros. & Co., Props	Portsmouth	Suffolk
Staunton Realty Corporation	Staunton	Staunton
Stonega Coke & Coal Co. (Formerly Keokee Coal & Coke Co.)	Keokee	Keokee
Stringfellow, S. P., Recvr., American Hygienic Fire Brick-Tile Fireproofing Co., Inc	Richmond	Richmond
Suffolk Clay Co	Suffolk	Ladysmith
Sweet Briar Institute	Sweet Briar	Sweet Briar
Taliaferro, J. L	Richmond	Richmond
Travis, Frank M	New London	New London
Turner, Mrs. Agnes L	Ferguson's Wharf	Ferguson's Wharf
Turner, W. R	Petersburg	Ettrick
Updike, Eston	Charlottesville	Charlottesville
Updike & Bro., R. L	Charlottesville	Charlottesville
Virginia Brick Co	Washington, D. C	Arlington
Virginia Brick Co	Seven Mile Ford	Seven Mile Ford

OPERATOR	OFFICE	WORKS
Virginia Brick Co	Suffolk	Suffolk
Virginia Brick Works	Richmond	East Fulton
Virginia Clay & Material Co., Inc	Farmville or Philadelphia, Pa	Hawk
Virginia Railway Co. (Formerly Lantry Ballast Co.)	Norfolk	Pembroke
Vulcan Fire Brick Co	Baltimore, Md	Wilmont
Walker Brick Co	Washington, D. C.	Arlington
Ward Brick Co	Galax	Galax
Ward & Cornett	Elk Creek	Elk Creek
Washington Brick & Terra Cotta Co	Washington, D. C.	Riverside Park
Watson Brick Corporation, John T.	Danville	Danville
Waverly Brick Co., Inc	Petersburg	Waverly
West Bros. Brick Co	Washington, D. C.	Arlington
West End Brick Co	Suffolk	Suffolk
Wetherell, Geo. W.	Blackstone	Blackstone
Whitfield Bros	Suffolk	Suffolk
Williamson, Chas. E.	Petersburg	Petersburg
Williamson, Hedgecock & Fontaine, Inc.	Martinsville	Fontaine
Wine, J. W.	Mt. Sidney	Mt. Sidney
Wood & Futrell	Emporia	Emporia
Young, Wm. J.	Manassas	Manassas
Zirkle, W. H.	Broadway	Broadway
	POTTERY	
Adamant Porcelain Co., Ltd	Broadway	Broadway and Harrisonburg
Akron Smoking Pipe Co	Mogadore, Ohio	Pamplin City
Bell Bros	Strasburg	Strasburg
Powhatan Pipe Co	Michaux	Michaux
	RAW CLAY	
Branch, John P.	Richmond	City Point
Dickinson Fire Brick Co	Buena Vista	Buena Vista
Frazer Paint Co	Bedford City	Bedford City
McNicol, John A., Recvr., Blue Ridge Kaolin Co	East Liverpool, Ohio	Oak Level, R. D. Edgewood
Powhatan Clay Mfg. Co	Richmond	Clayville
Swineford, Howard	Richmond	Bermuda Hundred
Virginia Clay & Material Co	Farmville	Hawk
Warrell, N. J. & B. E.	Sylvatus	Sylvatus

LIME AND CEMENT.

Lime and cement are obtained from limestone, which is described on pages 77 to 82, inclusive. Plants for their manufacture are scattered widely over western Virginia, where raw material, admirably adapted to the manufacture of lime and cement, occurs in great abundance. Plants for the burning of lime are found in most of the counties west of the Blue Ridge, while the manufacture of Portland cement is limited at present to two mills, one in Augusta County, the other at

Norfolk. Mills for the manufacture of natural cement are limited to Rockbridge and Botetourt counties. There was no reported production of natural cement in the State for the years 1909 and 1910.

LIME.

During recent years, lime-making in Virginia has been confined to the counties west of the Blue Ridge, where there are numerous plants engaged in the industry. There occur abundant limestones throughout this region admirably adapted to the making of lime. These range from very pure limestones to those high in magnesia. The former when burned or calcined yield "high limes" or "fat limes," while the latter produce "lean" or magnesian limes. Most of the lime made in Virginia belongs to the first class, and is especially valued by the builders and farmers.

The crystalline limestones of the Piedmont Plateau yield when calcined a good grade of lime. Formerly, numerous small kilns were operated within the limits of this region for the production of lime to supply only immediate local demands. In recent years, however, these have been abandoned, and at present no lime is burned from the Piedmont limestones.

The shell marls of the Coastal Plain region are dug and used locally, in the natural state, as fertilizer on the farming lands. These marls frequently form extensive deposits of considerable purity, and since they occur as loose incoherent material, and usually in a finely comminuted state, they can be easily dug and readily applied in the natural state to the soil.

The total production of lime in Virginia in 1909 was 166,695 short tons, valued at $635,946, as compared with 107,209 short tons, valued at $424,374 in 1908. This represents an increase of approximately 55.5 per cent in quantity (59,486 short tons) and 49.8 per cent in value ($211,572). The average price per ton in 1909 was $3.81½ as against $3.95 in 1908. This production was distributed over twelve counties and forty-nine producers. The counties producing lime in 1909 were Augusta, Botetourt, Frederick, Giles, Loudoun, Montgomery, Rockbridge, Rockingham, Russell, Shenandoah, Tazewell, and Warren.

The production of lime in Virginia during 1910 amounted to 141,257 short tons, valued at $563,567. Compared with the figures for 1909, it will be seen that there was a decrease of 25,438 short tons in quantity and $72,379 in value. There were forty-eight producers of lime in the State during 1910, and the production was distributed among the following 14 counties: Augusta, Botetourt, Frederick, Giles, Loudoun, Montgomery, Norfolk, Roanoke, Rockbridge, Rockingham, Russell, Shenandoah, Tazewell, and Warren.

There are given in the table below the production and value of lime in Virginia during 1909 and 1910, by counties.

Production and value of Lime in Virginia in 1909 and 1910, by counties.

County	1909		1910	
	Production Short tons	Value	Production Short tons	Value
Augusta	3,035	$ 10,552	1,671	$ 5,795
Botetourt	30,521	115,069	25,137	95,012
Frederick	29,668	102,500	28,323	106,258
Montgomery	13,370	69,708	(a)	(a)
Rockingham	4,652	16,258	4,548	16,829
Shenandoah	32,164	131,677	45,798	198,186
Other counties[a]	53,285	190.182	35,780	141,437
Total	166.695	$635,946	141,257	$563,567

[a] Includes during 1909, Giles, Loudoun, Rockbridge, Russell, Tazewell, and Warren; and during 1910 those of 1909 and the additional counties, Montgomery, Norfolk, and Roanoke.

In the table below is given the production of lime in Virginia in 1909 and 1910, by uses.

Production of Lime in Virginia, in 1909 and 1910, by uses, in short tons.

	1909		1910	
	Quantity	Value	Quantity	Value
Building lime	89,546	$361,896	76,361	$322,529
Hydrated lime	(a)	(a)	....	....
Paper mills	(b)	(b)	13,714	45,215
Fertilizer	57,606	205,896	33,766	118,419
Gas works	....	....	....	....
Tanneries	1,176	4,489	1,774	6,013
Chemical works	(b)	(b)	3,264	12,641
Dealers—uses not specified	8,045	28,068	12,378	58,750
Other purposes	22	115	....	....
Miscellaneous[c]	10,300	35,482	....	....
Total	166,695	$635,946	141,257	$563,567

[a] Only a small quantity of the lime produced in Virginia is hydrated.
[b] Included under miscellaneous.
[c] Includes gas and chemical works.

LIST OF LIME OPERATORS

OPERATOR	OFFICE	KILN
Alleghany Lime Co., Inc	Christiansburg	Houchin Station
Andrews & Co., Inc., T. C	Norfolk	Norfolk
Beinkampen Lime Co	Radford	Radford
Blankenship, S. M	Deerfield	Deerfield
Bristol Lime & Stone Co., Inc	Bristol, Va.-Tenn	Benhams
Church, E. W	Staunton	Craigsville
Conner, I. N	Vaucluse Station	Vaucluse Station
Cooper, I. C	Hinton	Hinton
Coverston, Eli and Samuel	Pelton	Seven Fountains
Crann, I. N	Bridgewater	Mossy Creek
Davis, C. W	Blacksburg	Blacksburg
Davison, Louis F	Harrisonburg	Harrisonburg
Dillon's Sons, E	Indian Rock	Indian Rock
Eagle Rock Lime Co	Richmond	Eagle Rock
Eureka Lime Co	Vicar Switch	Vicar Switch
Evers, D. L	Bridegwater	Mossy Creek
Fellsworth Lime Works	Staunton	Staunton
Fox, J. W	Ottobine	Ottobine
Grove Lime Co., M. J	Limekiln, Md	Stephens City
Haldeman, H. F	Churchville	Churchville

OPERATOR	OFFICE	KILN
Harris, J. A	Stuarts Draft	Stuarts Draft
Herbaugh, Robert L	Zepp	Zepp
Hoag Co., William N	Strasburg or New York, N. Y.	Strasburg
Hogshead, Thos. K	Sangerville	Sangerville
Hogshead, Charles A	Mossy Creek	Mossy Creek
Huggins & Co., H. H	Roanoke	Roanoke
Kiracofe, C. S	Bridgewater	Bridgewater
Kirk, John Y	West Norfolk	West Norfolk
Leesburg Lime Co., Inc	Leesburg	Leesburg
Limeton Lime Co	Limeton	Limeton
Linville Lime Co	Linville	Linville
Luray Lime Co	Eura	Luray
McIlwee, C E	Zepp	Zepp
McKimmy, A. G	Luckets	Luckets
Michael, J. W	Springcreek	Sangerville
Miller, E. X.	Bridgewater	Bridgewater
Moore Lime Co	Richmond	Eagle Rock
Natural Bridge Lime Co	Glasgow	Sherwood
New River Lime Co	Ripplemead	Ripplemead
Oak Ridge Lime Firm	Mt. Solon	Mt. Solon
Orndorff, M. M	Oranda	Oranda
Oyler, George V	Winchester	Winchester
Powhatan Lime Co	Strasburg	Strasburg
Pullins, A. C	Mount Sidney	Mount Sidney
Rawley, N. B	Churchville	Churchville
Riverton Lime Co	Riverton	Riverton
Roanoke Stone & Lime Co., Inc	Roanoke	Lithia
Rockbridge Lime & Stone Co	Lexington	Lexington
Rockdale Lime Co	Toms Brook	Toms Brook
Rusmiselle, J. A	Mt. Solon	Mt. Solon
Sanger, C. D. and M. G	Sangerville	Sangerville
Senger, D. M	Mt. Solon	Mt. Solon
Shenandoah Lime Co	Strasburg Jct	Strasburg Jct.
Shenandoah Lime & Stone Co	Strasburg	Strasburg
Shinault, C. W	Deerfield	Deerfield
Shoop, Withers Co	Suffolk	Suffolk
Snarr, G. H	Wheatfield	Wheatfield
Stuart Land & Cattle Co	Elk Garden	Elk Garden
Tazewell White Lime Works	North Tazewell	North Tazewell
Thompson, T. W	Hinton	Hinton
Wheelbarger-Rumsey Lime Cor	Bridgewater	Bridgewater
Whitesell, D. E	Stuarts Draft	Stuarts Draft
Wine & Wright	Spring Creek	Spring Creek
Wingate & McGhee	Roanoke	Roanoke
Woodstock Lime Co., Inc	Woodstock	Woodstock

CEMENT.

Although the cement industry may be said to be in its infancy in Virginia, yet the manufacture of this important economic product has been carried on for many years at one locality, and for a less time at another. Natural cement has been burned at Balcony Falls for over a half century. The demand for a cheap and trustworthy cement for use in the construction of masonry, locks, and walls on the James River canal, led to the discovery of the hydraulic properties of the rock used at this plant. Since that time a natural cement has been manufactured at this locality almost continuously, the James River Cement Company operating the plant at present. The rock used is a blue, argillaceous limestone of Lower Cambrian age, with an average thickness of 12 feet.

There are only two plants for the manufacture of Portland cement in Virginia in operation at present, namely, that of the Virginia Portland Cement Company at Fordwick, Augusta County, and that of the Norfolk Portland Cement Corporation at Norfolk. The Fordwick plant has a capacity of 1,250,000 barrels, and is selling the Old Dominion cement in the North as well as in the South. The materials used by this plant in the manufacture of Old Dominion cement are Lewistown limestone and shale. The Norfolk plant is the first plant built in the South to manufacture Portland cement from shell marl as the principal calcareous material instead of the hard rock—limestone. The marl and clay deposits used by this plant are located on branches of James River near Smithfield and Chuckatuck.

Two additional plants of large capacity have been granted charters for the manufacture of Portland cement in Tidewater (Coastal Plain) Virginia. These are the Jamestown Portland Cement Company's plant to be located at Yorktown, and the Colonial Portland Cement Company's plant to be located near Grove. The raw materials to be used by these plants for the manufacture of Portland cement will be the Miocene marls and clays of the immediate area.

There being only two plants in Virginia producing Portland cement in 1910, the figures of production are combined with those of another subject in order to avoid disclosing individual operations.

Virginia possesses an abundance of raw materials from which cement can be made—an economic resource which will prove of great value. The Appalachian Valley and the various mountains and valleys westward, an area of 350 or more miles long and averaging 50 miles in width, contains limestones and shales equal in value and abundance to those of any other region. The State Geological Survey has issued a valuable report[a] on the Cement Materials west of the Blue Ridge. This report is based on several seasons of careful investigations in the field, and contains an unusually large number of chemical analyses made of the limestones and shales from all parts of the region.

Four prominent sources of cement material obtain in western Virginia. Named in geologic order, these are:

4. Greenbrier (Mississippian) limestone.
3. Lewistown (Helderbergian) limestone.
2. Ordovician (Trenton, etc.) limestones and shales.
1. Cambrian—impure limestone and shale.

Of these, the limestones and shales of Ordovician age are the most promising on account of their abundance, widespread distribution, and usually favorable chemical composition. The Lewistown limestone is now used in the manufacture of Portland cement at Craigsville, Augusta County, and the Greenbrier limestone will probably become an important source of cement material in southwestern Virginia.

The most important cement materials of western Virginia are found in the pure and argillaceous limestones of Cambrian and Ordovician age, and in the calcareous and argillaceous phases of the Ordovician shales. These shales and limestones have a wider distribution and are usually more accessible than other cement rock horizons of the State, such as the Lewistown of Helderbergian age, and the Mississippian or Subcarboniferous (Greenbrier) limestone. In general the entire Valley of Virginia is underlain by the Cambrian and Ordovician limestones, while the shales usually outcrop along the base of the mountains bounding it. In a similar manner, many of the valleys west of the Great Valley show these limestones and shales, higher formations occurring on the separate ridges.

Three classes or groups of hydraulic cements[b] are recognized, and materials for their manufacture occur in Virginia. Named in the order of their importance, these are: (1) Portland cement, (2) Natural cement, and (3) Puzzolan cement.

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[a] Bassler, R. S., Virginia Geological Survey, Bulletin No. II-A, 1909.

[b] Ibid., 1909, pp. 5-32.

Eckel, E. C., Cements, Limes, and Plasters: Their Materials, Manufacture, and Properties. John Wiley and Sons, New York, 1907.

In the manufacture of Portland cement, a finely ground mixture containing lime, silica, alumina, and iron oxide, in exactly determined proportions, is burnt at a temperature approaching 3,000° F. This burning produces a semi-fused mass called "clinker" which, as a last step in the process of manufacture, must be finely ground. The theoretical mixture employed for burning consists of 75 per cent calcium carbonate, 20 per cent iron, alumina, and silica, and 5 per cent allowed for magnesium carbonate and other substances. This ideal composition is seldom realized in nature and, as a rule, an artificial combination is made by mixing limestone or marl with clay or shale. In this case, one part of the clayey materials is generally added to three parts of pure limestone.

The raw material from which natural cement is made is an argillaceous limestone carrying from 13 to 35 per cent of clayey material, of which about 10 to 22 per cent is silica, while alumina and iron oxide together may vary from 4 to 16 per cent. Unlike Portland cement rock, the percentage of magnesium carbonate may run high, the reason for this being that in natural cements the magnesia and lime are regarded as interchangeable. The hydraulic properties do not depend upon the percentage of lime but upon the clayey materials, which are the important factors to consider in the rock analysis.

Limestones having a composition within the limits just indicated are more or less abundant at several horizons in western Virginia, but probably the only one which will meet all the requirements and prove of economic importance is the argillaceous magnesian limestone of the lower part of the Shenandoah group. This rock, although often very similar in lithologic characters to the dolomitic limestone found higher in the Shenandoah group, can be recognized as containing argillaceous matter by the clayey odor given forth when breathed upon.

These limestones (Sherwood) and shales (Buena Vista) form the source of the rock used by the James River Cement Works, near Balcony Falls, Virginia, for making natural cement. These strata are found at various points along the eastern side of the Appalachian Valley in Virginia, so that a considerable supply of the necessary materials should be available.

The erection and operation of Portland cement plants, such as are now proposed in Tidewater Virginia, will have a stimulating influence on the entire industrial activity of the State.

LIST OF CEMENT OPERATORS

OPERATOR	OFFICE	PLANT
James River Cement Co.	Balcony Falls	Balcony Falls
Norfolk Portland Cement Corporation	Philadelphia, Pa	Norfolk
Virginia Portland Cement Co.	New York, N. Y.	Fordwick

SAND AND GRAVEL.

The production of sand and gravel in Virginia during 1909 amounted to 847,476 short tons, valued at $281,177, as compared with 449,234 short tons, valued at $119,095, in 1908, which represents an increase of 398,242 short tons, or 88.67 per cent, in quantity, and $162,082, or 73.47 per cent, in value. The 1910 production was 764,321 short tons, valued at $215,416.

These figures do not represent the total production of sand and gravel in Virginia, as large quantities are produced and utilized each year in the manufacture of brick, and in railway, highway, and sidewalk construction, etc., of which no record of the quantity used is kept and no returns are made to the office of the State Survey. Much the largest proportion of sand used in the State, for which returns are made, is for building and molding. In 1909, there were 33 producers of sand and gravel operating in 20 counties, and in 1910, 33 producers operating in 19 counties. The production of sand in Virginia during 1910, by counties, was as follows: Elizabeth City, 56,272 short tons, valued at $31,229; Giles, 19,400 short tons, valued at $11,590; Henrico, 29,391 short tons, valued at $24,947; Roanoke, 6,500 short tons, valued at $2,625; Rockingham, 5,005 short tons, valued at $2,381; other counties,[a] 200,552 short tons, valued at $54,853.

The following table shows the details of the industry, and the comparative quantities and values from 1905 to 1910, inclusive.

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[a] Includes Alleghany, Alexandria, Amherst, Carroll, Campbell, Charles City, Norfolk, Princess Anne, Prince George, Pulaski, Scott, Shenandoah, Washington, and Wise.

Production of Sand and Gravel in Virginia, 1905-1910, by uses, in short tons.

	1905		1906		1907	
	Quantity	Value	Quantity	Value	Quantity	Value
Sand—						
Glass	....	....	....	....	1,246	$ 4,535
Molding	61,246	$ 37,899	26,654	$ 15,466	50,627	30,377
Building	244,572	96,248	272,396	91,265	158,715	67,160
Fire	810	405	1,000	500	....	....
Engine	4,775	3,580	4,370	1,970	10,239	4,603
Furnace	4,212	2,665	21,376	8,028	10,059	4,227
Other	250	330	8,602	4,072	24,334	9,958
Gravel	35,250	13,453	780	650	13,002	2,952
Total	351,115	$154,580	335,178	$121,951	268,222	$123,812

	1908		1909		1910	
	Quantity	Value	Quantity	Value	Quantity	Value
Sand—						
Glass	....	....	....	....	700	$ 450
Molding	47,888	$ 22,568	25,480	$ 17,241	35,517	24,954
Building	139,742	61,378	368,744	125,208	251,170	88,340
Fire	....	....	....	....	....	....
Engine	6,651	2,860	3,594	1,585	1,900	1,165
Furnace	11,295	5,500	9,740	4,563	5,339	2,088
Other[a]	670	325	47,631	8,149	22,494	10,628
Gravel	242,988	26,464	392,287	124,431	447,201	87,791
Total	449,234	$119,095	847,476	$281,177	764,321	$215,416

[a] Includes for 1910 polishing and filtration sand.

LIST OF SAND AND GRAVEL OPERATORS

OPERATOR	OFFICE	BED OR PIT
Adair, James	Lurich	Lurich
American Locomotive Co	Richmond	Richmond
Appomattox Iron Works	Petersburg	Petersburg
Bickford Sand & Gravel Co., Inc	Hampton	Hampton
Bolton, John T	Norfolk	Hampton
Botto Sand Co., J. L	Richmond	Richmond
Bromilaw Brick Co	Alexandria	Alexandria
Calhoun & Bro., James W	North River	North River
Carter, Mrs. M. E	Buddle	Pulaski City
Catawba Valley Ry. & Mng. Co	Salem	Salem
Cavedo, W. L	Richmond	Richmond
Chesapeake & Ohio Railway Co	Basic City	Basic City
Cheshire & Sons, J. W	Martinsville	Martinsville
Christian, J. H	Providence Forge	Providence Forge
Clinedinst, Jno. S	Edinburgh	Edinburgh
Columbia Granite & Dredging Co	Washington, D. C	Potomac River
Cooper Glass & Silica Co	Salem	Salem
Cowardin, S. P	Richmond	Richmond
Cuddy, W. T	Lurich	Lurich
Curlis, H. C	Holdcroft	Holdcroft
Darst, Jno. C	Bluff City	Bluff City
Derbyshire, Mrs. M. J	Richmond	Richmond
Dills, M. C	Bluff City	Pearisburg
Eanes, A. W	Roanoke	Roanoke
French & Bro., J. E	Curve	Curve
French, K. S	Narrows	Narrows
Gibboney Sand Bar Co., Inc	Berton	Berton
Gill, E. F	Providence Forge	Providence Forge.
Gill & Bro., J. M	Providence Forge	Providence Forge
Gochenour, J. J	Maurertown	Maurertown
Goddin Supply Co., Inc	Richmond	Richmond
Harbaugh, Mrs. S. I	Richmond (Fairmont)	Richmond
Hoxall, L	Providence Forge	Providence Forge
Hunter Farmers Friend Plow Works, The Charles E	Fredericksburg	Fredericksburg
International Sand & Material Co	Norfolk	Norfolk
Ivanhoe Furnace Co	Ivanhoe	Ivanhoe
Jackson, D. E	Galts Mill	James River
Johnston, J. Raleigh	Bluff City	Bluff City
Laughon & Co., B	Pulaski	Laughon Siding
Lillie, Geo. W	Richmond	Richmond
Linkous, R. T.	Narrows	Narrows
Lowmoor Iron Company of Virginia	Lowmoor	Lowmoor
Maupin, R. W	Waynesboro	Waynesboro
Monger, Jno. H	North River	Harrisonburg
Myers, J	Roanoke	Roanoke
National Mfg. Co., Inc	Lynchburg	Lynchburg
Norfolk Railway & Light Co	Norfolk	Norfolk
Norfolk & Southern Railway Co	Norfolk	Cape Henry
Perkinson & Finn	Petersburg	Petersburg
Port Republic Foundry	Port Republic	Port Republic
Presque Gravel Co	Norfolk	James River Dutch Gap Ocher Petersburg

OPERATOR	OFFICE	BED OR PIT
Pure Silex Co.	Scottsville	Scottsville
Quarles, A. G.	Richmond	Richmond
Radford, Mrs. Emma	Richmond	Richmond
Richardson, R. E.	Providence Forge	Providence Forge
Richmond, Fredericksburg & Potomac Railway Co.	Richmond	Bowling Green Fredericksburg
Rodgers, James M.	James River	James River
Rogers, E.	Ivanhoe	Ivanhoe
Sellers, Dr. J. S.	Weyers Cave	Weyers Cave
Shepherd, Larkin	Appalachia	Appalachia
Slaughter & Griffin	Fredericksburg	Fredericksburg
Umstadler, J. M.	Norfolk	Norfolk
Water Works Supply Corporation	Norfolk	Norfolk
Webb J. H.	Roanoke	Glad Creek
Wills, T. L.	Lynchburg	Lynchburg

SAND-LIME BRICK.

The term sand-lime brick is used "to cover all brick made by mixing sand or gravel with a relatively small percentage of slaked lime, pressing the mixture into form in a brick mold, and drying and hardening the product either by sun heat or artificial methods."[a]

The manufacture of sand-lime brick in Virginia commenced only a few years ago. The total number of sand-lime brick produced in 1908 was 6,181,000 brick, valued at $36,934, of which 6,123,000 were common brick valued at $36,184. On account of there being only two producers of sand-lime brick in the State during 1909, the figures are given under "Other products" in the table on page 5, in order to avoid disclosing individual production. The 1910 production of sand-lime brick in Virginia is included under "Other products" in the table on page 6.

LIST OF SAND-LIME BRICK OPERATORS

OPERATOR	OFFICE	WORKS
Cape Henry Granite Brick Corporation	East Radford	East Radford
New River Sandstone Brick Co.	East Radford	East Radford
Norton Silica Brick Co.	Norton	Norton
Old Dominion Granite Brick Co.	Cape Charles	Cape Charles
Virginia Sand-Lime Brick Co.	Norfolk	Norfolk

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[a] Eckel, E. C. Cements, Limes, and Plasters: Their Materials, Manufacture, and Properties. John Wiley and Sons, New York, 1907.

STONE.

The production of stone has been an important industry in the State for many years, and the product of some varieties, especially granite, has been used in many notable structures. The rocks of Virginia include a large variety and abundance of excellent stone suitable for building, decorative, and other purposes. These have wide distribution over the Crystalline and Mountain provinces, comprising in the former, granite, gneiss, and schist, trappean rocks, in part known to the trade as black granites, slate, quartzite and sandstone, limestone and marble; and in the latter, sandstone, limestone, and marble.

The stone industry is the fourth in importance among those based upon the mineral wealth of the State, being surpassed only by the coal, clay products, and iron ores. The value of the annual production of stone in Virginia from 1900 to 1910, inclusive, is given in the accompanying table.

Value of the annual production of Stone in Virginia from 1900 to 1910, inclusive.

Year	Granite Value	Sandstone Value	Slate Value	Limestone Value	Total Value
1900	$211,080	$ 6,000	$190,211	$403,318	$ 810,609
1901	275,701	5,303	178,979	986,177	1,416,160
1902	282,046	2,500	160,951	534,113	979,610
1903	299,335	4,471	115,356	569,205	988,367
1904	510,788	13,522	130,208	442,978	1,097,496
1905	452,390	2,000	146,786	212,660	813,836
1906	340,900	5,100	172,857	260,343	779,200
1907	398,426	(a)	173,670	362,062	935,158
1908	321,530	2,600	194,356	280,542	799,028
1909	488,250	28,574	180,775	342,656	1,040,255
1910	503,106	25,080	148,721	471,903	1,148,810

[a] Small value included with West Virginia.

The total value of the different kinds of stone quarried for the period of years for which statistics are given, shows that the quarrying of limestone is the largest industry in stone, with granite next, and slate third. For the past several years granite has been of first importance, although the difference in the annual value of its production and that of limestone is very small. The variation in limestone production is controlled in large part by the blast furnace conditions where it is used as a flux. The production of sandstone for the period represented in the table is relatively unimportant.

The value of the total production of stone in the State during 1909 was $1,040,255, while the value for 1910 was $1,148,810.

GRANITE.

Granites, including the foliated type gneisses, have very wide distribution throughout the Virginia Piedmont region, constituting one of the dominant rock types. The general excellence of the Virginia granites as a building and ornamental stone has long been established in the commercial world. There is not a county within the limits of the Piedmont region that does not contain some granite, but the quarrying industry has thus far been limited to less than half a dozen counties. The principal producing areas of massive granites are distributed along the eastern border of the Piedmont Plateau. They include (1) the Petersburg area, (2) the Richmond area, and (3) the Fredericksburg area. The principal counties composing these areas are Dinwiddie, Chesterfield, Henrico, and Spottsylvania. A small amount of granite has been quarried in a number of other counties within the limits of the Piedmont to supply strictly a local demand.

The granites of the State are chiefly granular aggregates of the minerals quartz, feldspar, and mica. Hornblende and epidote are important minerals in the granites of a few localities in the State, the latter being conspicuous in the variety of granite known as unakite, which is found in Madison, Page, and Grayson counties. Based then on mineral composition, we have the following varieties of Virginia granite: (1) Biotite granite, under which vastly the majority of the granites of the State belong; (2) muscovite granite; (3) hornblende-biotite granite; and (4) epidote granite.

The chemical composition of the granites in the Richmond, Petersburg, and Fredericksburg areas is shown in the table of analyses on page 73.

Analyses of Virginia Granites.

(WM. M. THORNTON, JR., *Analyst.*)

Constitutents	I	II	III	IV	V	VI	VII	VIII
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Silica (SiO_2)	72.27	71.51	71.19	70.83	69.48	69.44	69.29	68.45
Alumina (Al_2O_3)...........	14.30	13.82	14.01	12.70	13.95	15.46	14.07	10.00
Ferric oxide (Fe_2O_3).......	1.16	1.76	1.66	2.67	2.82	1.31	2.59	5.71
Ferrous oxide (FeO).......	0.97	1.20	1.29	1.36	1.70	1.43	2.03	2.59
Magnesia (MgO)	0.70	0.80	0.44	0.53	1.10	1.01	1.32	3.26
Lime (CaO)	1.56	1.79	2.04	1.88	2.81	2.11	2.76	6.20
Soda (Na_2O)	3.46	3.64	3.56	3.49	3.65	3.97	2.89	1.98
Potash (K_2O)	5.00	4.63	4.45	4.83	3.45	4.25	2.87	1.18
Water (H_2O) —110° C......	0.04	0.17	0.04	0.07	0.04	0.07	0.06	0.18
Water (H_2O) +110° C.....	0.25	0.31	0.33	0.34	0.50	0.29	0.37	0.62
Titanium oxide (TiO_2)....	0.31	0.33	0.35	0.41	0.47	0.48	0.50	0.20
Manganese oxide (MnO)....	trace	0.03	0.02	0.03	0.03	0.03	0.08	0.05
Carbon dioxide (CO_2).....	0.21	trace	trace	trace	trace	trace	trace	trace
Phosphoric acid (P_2O_5)...	0.02	0.30	0.34	0.33	0.49	0.22	0.26	0.25
Total	100.25	100.29	99.72	99.47	100.49	100.07	99.09	100.67

I. Medium-textured and medium gray, biotite granite. Westham granite quarries, 4.5 miles west of Richmond, Chesterfield County.

II. Medium-textured and medium gray, biotite granite. Lassiter and Petersburg Granite Co.'s quarries, Petersburg, Dinwiddie County.

III. Fine-grained, dark blue-gray, biotite granite, McGowan, Netherwood, and Donald quarries, Chesterfield County, and Mitchell and Copeland quarry, Henrico County, near Richmond.

IV. Medium coarse-textured and medium gray, biotite granite. Netherwood, State (Old Dominion), Granite Development Co., Krimm and Middendorf quarries, Chesterfield County, near Richmond.

V. Fine-grained, dark blue-gray, biotite granite. Cartwright and Davis quarries, near Fredericksburg, Spottsylvania County.

VI. Medium-textured and medium gray, biotite granite. McIntosh quarry, Chesterfield County, 5 miles west of Richmond.

VII. Medium coarse-textured, gray, biotite granite-gneiss. Middendorf (Belt Line Railway) quarry, near Manchester, Chesterfield County.

VIII. Medium coarse-textured, gray, biotite granite-gneiss. Cartwright and Davis quarries, near Fredericksburg, Spottsylvania County.

The Richmond area is the principal granite-producing area in the State. Not less than 20 quarries have been worked within the limits of the area, some of which are very extensive, being worked to a depth of nearly 200 feet. Two grades of granite are quarried, one a fine-grained, dark blue-gray rock, extensively used as monument stock, the other a coarser grained and lighter colored gray rock admirably suited for building purposes. Both are homogeneous even-granular granites, possessing good working qualities. The fine-grained, dark blue-gray granite is susceptible of a high and permanent polish, and is a superior monumental stone.

Under the general head of granite are included in the trade such crystalline rocks as syenite, diorite, gabbro, and diabase, and the banded rocks known as gneiss and schist.

The production of granite during 1909 was valued at $488,250, as against $321,530 in 1908, a gain in value of $166,720, or nearly 52 per cent. Twelve counties contributed to this production, namely, Alexandria, Amherst, Campbell, Chesterfield, Dinwiddie, Fairfax, Goochland, Greenesville, Henrico, Pittsylvania, Prince Edward, and Stafford. The uses made of the stone and the value of each are given in the table below. The 1910 production of granite in Virginia was valued at $503,106.

There are given in the tables below the value and uses of the granite and gneiss quarried in Virginia during the years 1900 to 1910, inclusive.

Value of Granite produced in Virginia, 1900-1910, by uses.

Use		1900	1901	1902
Sold in the rough	Building	....	$ 40,763	$ 21,158
	Monumental	$ 12,000	8,300	12,500
	Other	....	230	....
Dressed for building		55,296	45,737	28,840
Dressed for monumental work		21,461	52,404	51,612
Made into paving blocks		16,605	17,253	14,845
Curbing		8,810	7,977	29,796
Flagging		....		
Rubble		....	43,029	26,255
Riprap		15,833		17,215
Crushed stone	Road-making	38,850	9,850	6,133
	Railroad ballast		7,841	25,554
	Concrete		42,317	46,588
Other		....	....	1,000
Total		$211,080	$275,701	$282,046

Value of Granite produced in Virginia, 1900-1910, by uses.—Continued.

1903	1904	1905	1906	1907	1908	1909	1910
$ 26,345	$ 33,613	$ 31,224	$ 18,158	$ 19,350	$ 26,769	$ 24,965	$ 31,841
13,440	17,320	10,415	15,804	8,039	12,664	1,966	3,771
....	....	....	200	....	1,075	....	2,375
14,740	48,452	28,950	....	13,275	4,000	17,750	14,750
43,845	55,608	37,180	16,936	9,787	29,803	9,449	6,300
28,034	30,966	19,220	29,536	18,072	10,173	18,053	28,596
4,582	33,324	8,948	14,339	6,000	6,130	29,100	57,511
5,485	3,516	2,550	1,216	....	....	990	1,565
28,449	40,524	28,961	28,477	16,350	18,270	33,321	38,792
22,410	7,630	27,236	31,790	28,852	16,336	1,386	6,989
31,785	12,940	21,175	34,981	59,937	21,670	74,054	40,691
17,400	61,352	69,360	64,386	50,804	92,895	125,704	111,811
60,820	165,043	166,364	85,077	167,960	81,745	147,112	156,894
2,000	500	807	....	....	....	4,400	1,220
$299,335	$510,788	$452,390	$340,900	$398,426	$321,530	$488,250	$503,106

In the table below is given the number of granite paving blocks produced in Virginia, by years, from 1904 to 1910, inclusive.

Number and value of Granite Paving Blocks produced in Virginia, 1904-1910.

Year	Number	Value	Average Value per 1,000
1904	1,032,200	$30,966	$30.00
1905	913,440	19,220	21.05
1906	1,385,000	29,536	21.32
1907	685,100	18,072	26.38
1908	252,910	10,173	40.22
1909	853,300	18,053	21.16
1910	680,602	28,596	42.02

LIST OF GRANITE OPERATORS

OPERATOR	OFFICE	QUARRY
American Stone Co., Inc	Richmond	Boscobel
Andrews & Co., J. W	Petersburg	Petersburg
Bedford, A. C	Richmond	Butterworth
Belmont Traprock Co., Inc	Belmont Park	Belmont Park
Brennan Construction Co. (Gneiss)	Washington, D. C	Chain Bridge
Brown, J. Henry	Richmond	Dunbarton Station
Butterworth, R	Butterworth	Pride
Cartwright & Davis	Fredericksburg	Fredericksburg
Casey, John B	Lynchburg	Lynchburg
Columbia Granite & Dredging Co	Washington, D. C	Washington, D. C.
Consolidated Quarry Co	Washington, D. C	Occoquan (near)
Cranford Paving Co. (Gneiss)	Washington, D. C	Washington, D. C.
Danville, City of	Danville	Danville
Echols & Co., J. M	Lynchburg	Lynchburg
Ford, J. R	Lynchburg	Lynchburg
Forge Granite & Lumber Co	Falmouth	Falmouth (near)
Fountain Creek Granite Co	Norfolk	Hitchcock
Fredericksburg Power Co	Fredericksburg	Fredericksburg
Hall, Wm. W	Lynchburg	Lynchburg
Harris, H. J	Richmond	Boscobel (Harris Siding)
Holland, H. S	Richmond	Buffalo Station
Island Granite Co., Inc	Richmond	Richmond
James River Granite Co	Richmond	Richmond (Holland Siding)
Jones, Harvey	Lynchburg	Lynchburg
Lane Bros. Co	Alta Vista	Alta Vista
Lee Stone Co	Lee	Lee
Lennox, John	Rio Vista	Rio Vista
Logan, A	Lynchburg, R.F.D.No.3	Lynchburg
Lone Jack Stone Co. (Gneiss)	Lynchburg	Lynchburg
McCloy Granite Co., John A	Richmond	Richmond
McGowan, John	Richmond	Manchester
McGranighan, P	Granite	Granite
McIntosh, Hugh (Chesterfield Granite Works)	Granite	Granite
Moncure, Pettitt & Moncure	East Falls Church (or Alexandria C. H.)	Falls Church
Morris & Lipscomb	Roanoke	Goodview
Nelson Stone Co., Taylor Gleaves	Lynchburg	Faber
Netherwood, Albin	Richmond	Richmond
Norfolk County Road Board	Norfolk	Emporia
Occoquan Stone & Lumber Co	Occoquan	Occoquan
Old Dominion Iron & Nail Works	Richmond	Belle Isle
Petersburg Granite Co	Baltimore, Md	Petersburg
Rockfish Ballast Co	Baltimore, Md	Rockfish
Slocombe, W. A	Farmville	Farmville
Slocombe & Hall	Lynchburg	Lynchburg
Smith & Co., Inc., I. J	Richmond	Richmond
Southern Quarry Co	Washington	Rockfish
Sunnyside Granite Co., Inc	Richmond, R.F.D No. 2	Richmond (Dunbarton Station)
Virginia Granite Co	Richmond	Dunbarton Station
Virginia Quarrying Corporation	Norfolk	Manchester
Virginia State Farm	Lassiter	Lassiter
Wakefield Granite Quarries	Petersburg	Petersburg
Wray, A. J	Richmond	Granite

MARBLE.

Marbles are found in the Mountain province west of the Blue Ridge and in the Piedmont province to the east, but there has been but slight attempt to develop them, owing chiefly to a lack of definite knowledge of their extent and quality. Bands occur in some of the limestones of the Mountain province, especially in the Shenandoah and Chickamauga formations, of a color and texture which adapt them to ornamental purposes. These show a variety of color and texture. White, gray, red, and black colors are found. These marbles have not received the attention which they apparently merit in places, and the developments thus far are slight.

Onyx marbles are fairly abundant in the limestone caves and caverns of the Valley region, but it is probable that these will rank as "uniques" rather than objects of commercial value. Large deposits of onyx marbles are found near Bridgewater in Rockingham County, but they have not been investigated and very little is known of their quality.

Marbles of excellent quality occur in the vicinity of Goose Creek, Loudoun County. Samples of the white marble are not excelled for purity of color, fineness of grain, and general excellence, by that of any other marble in the United States. At Goose Creek, the marble bed is about 52 feet thick and has been worked to a considerable depth. The varieties shown are chiefly white, but there occur, also, banded blue and white, serpentinized white and green, pink and white, and green and white. These beds are pure, and the stone is of great beauty and takes a good polish. The lack of transporation facilities has thus far prevented extensive quarrying.

Undeveloped areas of marbles are known in Grayson, Campbell, Nelson, and Pittsylvania counties. Openings were made in some of these many years ago and the stone burned into lime.

There has been no production of marble in Virginia for several years.

LIMESTONE.

Limestone has its greatest distribution in the region west of the Blue Ridge where it forms one of the dominant rock types. It has had only a limited use for building purposes, but has been extensively quarried for use as a furnace flux, for lime-making in building and agriculture, for road metal and ballast, for concrete, and for the manufacture of Portland and natural cements. Four prominent sources of limestone obtain in this region, which, named in geologic order, are:

4. Greenbrier (Mississipian) limestone.
3. Lewistown (Helderbergian) limestone.
2. Ordovician (Trenton, etc.) limestone.
1. Cambrian limestone.

Of these four principal divisions of limestones, the Cambrian and Ordovician limestones constitute the Shenandoah (Valley) limestone group, which is the most persistent limestone group in the State. It is the underlying or basement rock of the Great Valley (Shenandoah) of Virginia. The most important and only limestone which has been used in buildings is the Shenandoah limestone of the Great Valley. In its normal development, it is probably not less than 3,500 feet thick and in places it is much thicker. It has a wide range in composition and is divisible into several different members. The most important member of the Shenandoah limestone for building stone is the Natural Bridge limestone, which is usually a heavy-bedded, dark blue to gray magnesian limestone, frequently dolomitic. Quarries have been opened in it, in many places through the Valley region, and the stone used locally for building purposes.

The Lewistown and Greenbrier limestones have not been used for building purposes, but each has been quarried in places, especially the Lewistown, and used for fluxing the iron ores at the blast furnaces.

The value of limestone produced in the State during 1909 was $342,656, as compared with $280,542 in 1908. This represents a gain of $62,114, or slightly over 22 per cent, in value. This increase in production was due chiefly to an increased production of limestone for use as railroad ballast and fluxing purposes. There were 32 producers of limestone operating in fourteen counties of the State, as against 30 producers in 1908. There is given below in tabular form the value of limestone produced in Virginia in 1909, by counties.

Value of Limestone produced in Virginia in 1909, by counties.

County.	Value
Augusta	$ 5,081
Botetourt	59,695
Roanoke	13,511
Rockbridge	37,281
Other counties[a]	227,088
Total	$342,656

[a] Includes Alleghany, Giles, Lee, Loudoun, Rockingham, Russell, Shenandoah, Tazewell, Washington, and Wythe.

The production of limestone in Virginia during 1910 was valued at $471,903, which represents an increase in value over the 1909 production of $29,247.

There were 37 producers of limestone in the State during 1910, operating in the following 15 counties: Alleghany, Augusta, Botetourt, Giles, Loudoun, Pulaski, Roanoke, Rockbridge, Shenandoah, Smyth, Tazewell, Warren, Washington, Wise, and Wythe.

The production of limestone in Virginia from 1902 to 1910, inclusive, and the uses for which it was quarried are given in the table below:

Production of Limestone in Virginia from 1902 to 1910, by uses.

	1902	1903	1904	1905	1906
Rough building	$ 41,355	$ 5,325	$ 8,800	$ 5,390	$ 3,448
Dressed building			360	700	1,680
Paving					
Curbing					275
Flagging					
Rubble			168		
Riprap		22		120	323
Crushed stone:					
Road making		300	210	5,254	160
Railroad ballast	7,875	16,205	32,371	9,333	16,050
Concrete	11,580	9,238	5,668	11,187	18,700
Flux	220,001	199,989	117,882	180,676	219,707
Unspecified	11,318	1,665			
Total	$534,113	$569,205	$442,978	$212,660	$260,343

Production of Limestone in Virginia from 1902 to 1910, by uses.—Continued.

	1907	1908	1909	1910
Rough building	$ 3,170	$ 1,870	$ 715	$ 125
Dressed building	1,130	2,950	129	....
Paving	500	....	15	45
Curbing	....	79	....	750
Flagging	....	110	7	....
Rubble	....	....	3,000	3,188
Riprap	....	3,377	....	1,805
Crushed stone:				
Road making	37,000	30,159	31,076	20,056
Railroad ballast	12,269	45,541	84,883	108,129
Concrete	32,326	26,604	8,068	36.849
Flux	275,517	169,847	213,444	294,668
Unspecified	150	5	1,319	6,288
Total	$362,062	$280,542	$342,656	$471,903

LIST OF LIMESTONE OPERATORS

OPERATOR	OFFICE	QUARRY
Abingdon Construction Co	Abingdon	Abingdon
Alleghany Lime Co., Inc	Christiansburg	Houchin Station
Andrews & Co., Inc., T. C	Norfolk	Norfolk
Beinkampen Lime Co	Radford	Radford
Bertha Mineral Co., Inc	Pulaski	Austinville
Bradley, Samuel A	Newport	Newport
Bristol Lime & Stone Co., Inc	Bristol, Va.-Tenn	Benhams (near)
Bunn, J. E	Big Stone Gap	Big Stone Gap
Burks, Jas. L	Compton Bridge	Saltpetre Cave
Carpenter & Boxley	Roanoke	Pembroke
Carter, Walter H	Buchanan	Buchanan or Lithia
Childress, J. S	Christiansburg	Christiansburg
Chiles. C. M	Strasburg	Strasburg
Church, E. W	Staunton	Craigsville
Clifton Forge, City of	Clifton Forge	Clifton Forge
Compton, C. W	Roanoke	Compton Bridge
Compton Bridge Stone Corporation	Indian Rock	Compton Bridge
Covertson, Eli and Samuel	Pelton	Seven Fountains
Crann, J. N	Mossy Creek	Mossy Creek
Cregger, R. C	Wytheville	Wytheville
Cross & Mays	Eagle Rock	Eagle Rock
Culbert, W. F	Marion	Marion
Davidson, S. C	Max Meadows	Wytheville
Davis, C. W	Blacksburg	Blacksburg
Dillon's Sons, E	Indian Rock	Buchanan and Indian Rock
Eagle Rock Lime Co	Richmond	Eagle Rock
Eureka Lime Co	Vicar Switch	Vicar Switch
Fellers Stone Co	Roanoke	Roanoke
Fellsworth Lime Works	Staunton	Staunton
Fisher & Co., S. E	Strasburg	Strasburg Jct.
Flickwir, David W	Roanoke	Roanoke

OPERATOR	OFFICE	QUARRY
Fox, J. W	Ottobine	Ottobine
Fringer, C. F	Buchanan	Buchanan (or Lithia)
Gochenour, J. J	Mauertown	Maurertown
Goshen Iron Co	Goshen	Bells Valley and Craigsville
Grove Lime Co., M. J	Limekiln, Md	Stephens City
Haldeman, H. F	Churchville	Churchville
Hall, George B	East Radford	Snowville
Harris, J. A	Stuarts Draft	Stuarts Draft
Herbaugh, Robert L	Zepp	Zepp
Hoag Co., William N	Strasburg or New York, N. Y.	Strasburg
Hogshead, Charles A	Mossy Creek	Mossy Creek
Horneck Construction Co	Cumberland	Gate City
Huggins & Co., H. H	Roanoke	Roanoke
Ivanhoe Furnace Co	Ivanhoe	Ivanhoe
Keller, J. H	Fishers Hill	Fishers Hill
Kinzer & Vermillion	Tazewell	Tazewell
Kiracofe, C. S	Bridgewater	Bridgewater
Kirk, John Y	West Norfolk	West Norfolk
Kline, J. Harvey	Vaucluse Station	Vaucluse Station
Larner & Co., William	Staunton	Staunton
Leesburg Lime Co., Inc	Leesburg	Leesburg
Lexington, Town of	Lexington	Lexington
Limeton Lime Co	Limeton	Limeton
Linville Lime Co	Linville	Linville
Lowener, C. A	Harrisonburg	Rockingham
Lone Jack Stone Co	Lynchburg	Lynchburg
Longdale Iron Co	Longdale	Longdale
Lowmoor Iron Co. of Virginia	Lowmoor	Lowmoor
Luray Lime Co	Eura	Luray
McCoy, G. W	Springwood	Springwood
McGhee & Co., P. R	Roanoke	Roanoke
McIlwee, C. E	Zepp	Zepp
McKimmy, A. G	Luckets	Luckets
Markley, C	Roanoke	Roanoke
Mathews Curtis Co., Inc	Clifton Forge	Clifton Forge
May, A. J	Tazewell	Tazewell
Miller, G. Ed	Bridgewater	Bridgewater
Moore Lime Co	Richmond	Eagle Rock
Myers & Neville	Clifton Forge	Clifton Forge
Natural Bridge Lime Co	Glasgow	Sherwood
New River Lime Co	Ripplemead	Ripplemead
Oak Ridge Lime Firm	Mt. Solon	Mt. Solon
Oriskany Ore & Iron Corporation	Iron Gate	Mt. Marble
Orndorff, M. M	Oranda	Oranda
Oyler, Geo. V	Winchester	Winchester
Powhatan Lime Co	Strasburg	Strasburg
Pruver, W. W	Friendship	Friendship
Pulaski Iron Co	Pulaski	Patterson and Ivanhoe
Pullins, A. C	Mount Sidney	Mount Sidney
Rawley, N. B	Churchville	Churchville
Rife Bros	Timberville	Timberville
Riverton Lime Co	Riverton	Riverton
Riverton Lime Quarry Co	Leesburg	Leesburg
Roanoke Stone & Lime Co., Inc	Roanoke	Lithia

OPERATOR	OFFICE	QUARRY
Rockbridge Lime & Stone Co	Lexington	Lexington
Rockdale Lime Co	Toms Brook	Toms Brook
Rule, Pendleton	Abingdon	Abingdon
Sandridge, W. P	Goshen Bridge	Panther Gap
Shenandoah Iron & Coal Co	Liberty Furnace	Liberty
Shenandoah Lime Co	Strasburg Jct	Strasburg Jct.
Shenandoah Lime & Stone Co	Strasburg	Strasburg
Shoop Withers Co	Suffolk	Suffolk
Snarr, G. H	Wheatfield	Wheatfield
Snyder, E. A	Buchanan	Springwood
Staunton, City of	Staunton	Staunton
Stickley & Orndorff	Oranda	Oranda
Stoutamine, Jacob	Roanoke	Roanoke
Stuart Land & Cattle Co	Elk Garden	Elk Garden
Sutton, W. B	Mendota	Fugates Hill
Tazewell White Lime Works	North Tazewell	North Tazewell
Thompson, T. W	Hinton	Harrisonburg
Valley Turnpike Co	Mt. Jackson	Mt. Jackson
Vaughan Construction Co	Roanoke	Roanoke
Virginia Iron, Coal & Coke Co	Bristol, Tenn	Barren Springs, Buchanan, and Radford
Webb, J. H	Roanoke	Roanoke
Wells & Hanger	Staunton	Staunton
West End Furnace Co	Roanoke	Buchanan
Wheelbarger-Rumsey Lime Corp	Bridgewater	Bridgewater
Whitesell, D. E	Stuarts Draft	Stuarts Draft
Woodstock Lime Co., Inc	Woodstock	Woodstock
Wytheville Town Quarry	Wytheville	Wytheville

SANDSTONE.

Sandstones and quartzites occur in each of the three larger divisions of the State, but quarrying has been limited to only a few of the more accessible areas. There are large areas of these rocks not yet developed because chiefly of their remoteness from lines of railway and large centers.

The principal sandstone and quartzite formations in the State may be classified as follows:

COASTAL PLAIN:

1. Cretaceous sandstones along the "fall-line."

PIEDMONT PLATEAU:

2. Older quartzites in crystalline area of unknown age.
3. Newark (Triassic) sandstones.

APPALACHIAN MOUNTAINS:

4. Cambrian sandstones.
5. Silurian sandstones.
6. Devonian sandstones.
7. Carboniferous sandstones.

Excepting the areas of Triassic (Newark) sandstones, the quartzites and sandstones found east of the Blue Ridge, in the Crystalline area, are of unknown age. There occur an abundance and variety of this type of rock within the limits of the Piedmont. The rock has been quarried in many places, in years past, for use as a general constructional stone, and quarries are operated at present in a number of counties principally for crushed stone for road construction, ballast, and concreting. The stone ordinarily is firm, hard and compact, highly siliceous, very durable, and is admirably adapted to the uses made of it.

The Cretaceous and Triassic sandstones are practically the only ones which have been quarried and the stone shipped beyond the limits of the State. Of these, the Cretaceous sandstone, which occurs along the western margin of the Coastal Plain, was formerly extensively quarried in the vicinity of Aquia Creek and on the Rappahannock River near Fredericksburg. The stone from these quarries was used chiefly in the construction of many of the older public buildings in Washington. These quarries were abandoned many years ago, largely, it is said, because of the unfitness of the stone for exposed work.

There are seven areas of Triassic rocks, composed in part of sandstone, distributed over the crystalline region east of the Blue Ridge. These comprise parts of twenty counties, and are designated as follows: (1) New York-Virginia area, (2) Richmond area, (3) Danville area; (4) Farmville area, (5) Scottsville area, (6) Barboursville area, and (7) Taylorsville area. The Triassic sandstone has been quarried in the vicinity of Manassas, Prince William County, and in the vicinity of Leesburg and Oatlands, Fauquier County. The Manassas quarries have yielded a stone that could be used with pleasing effects in a variety of combinations, and in quality not inferior to that in the more northern and eastern states.

The Cambrian sandstones are chiefly limited in distribution to the western base of the Blue Ridge and have been quarried locally, especially east of Basic, Augusta County, for railroad ballast. Sandstones of Silurian age have wide distribution west of the Blue Ridge, but they vary much in color, texture, and structure. Although possessing the essential properties in places requisite for a general constructional stone, the Silurian sandstones have not been quarried except for immediate local needs. The Oriskany sandstone of Devonian age is generally too friable to make a good building stone.

The Carboniferous comprises the greatest total thickness of sandstones of any single geologic system in the State. The rocks belonging to this system are limited in distribution to certain parts of the region west of the Blue Ridge, and are in part Mississippian and in part Pennsylvanian in age. The Carboniferous sandstones possess those qualities in some localities which make them desirable for building purposes, but as yet they have seldom been quarried, owing largely to a lack of demand for the stone and ample transportation facilities. They have been quarried in places in southwest Virginia for local use as a building stone and for heavy masonry.

The production of sandstone in the State is slight, and it varies greatly according to the local demands. The value of the annual production of sandstone from 1900 to 1910, inclusive, is shown in the accompanying table.

Value of Sandstone production in Virginia, 1900-1910.

Year	Value
1900	$ 6,000
1901	5,303
1902	2,500
1903	4,471
1904	13,522
1905	2,000
1906	5,100
1907	(a)
1908	2,600
1909	28,574
1910	25,080

aSmall value included with West Virginia.

LIST OF SANDSTONE OPERATORS

OPERATOR	OFFICE	QUARRY
Gaithers Construction Co	Manassas	Nokesville
Hall, L. M	Wise	Wise
Mathews Curtis Co., Inc	Clifton Forge	Basic City
Peak Creek Sandstone Co	Pulaski	Pulaski
Portner Brown Stone Co	Manassas	Manassas
Warden & Hailley	Pulaski	Pulaski
Wood, J. R	Lynchburg	Lynchburg

SLATE.

Slate suitable for roofing and other purposes has been found in many localities within the limits of the State, and quarries have been worked in Albemarle, Amherst, Buckingham, Fauquier, and Fluvanna counties. There are five principal slate areas and several minor belts in Virginia, which, named in the order of their present commercial importance, are: (1) The Arvonia belt in Buckingham and Fluvanna counties; (2) the Keswick-Esmont belt in Albemarle County; (3) the Snowden belt in Amherst and Bedford counties; (4) the Warrenton belt in Fauquier and Culpeper counties; and (5) the Quantico belt in Spottsylvania, Stafford, and Prince William counties. These areas are being studied and mapped by the State Geological Survey when, upon the completion of the chemical and microscopical studies, a volume will be published for distribution. Of the slate areas worked, the Arvonia and Keswick-Esmont belts are commercially the most important at present.

The slate produced in the Arvonia district is the most widely known in the South. The quarries are distributed along Hunts Creek, for some distance north-northeast and south-southwest of Arvonia, a station on the Buckingham Branch of the Chesapeake and Ohio Railway, which is the shipping point. The quarries are very extensive, the largest averaging about 500 feet along the cleavage, 350 feet across, and 350 feet deep. The bedding and cleavage of the slate are identical, striking N. 33° to 37° E., and dipping 70° to 90° southeast, with a probable average of about 85°. The slate is very dark gray in color, with a faint greenish hue; is of minutely granular crystalline texture, and very lustrous surface. According to Dale, it is slightly graphitic and magnetitic, does not effervesce in cold dilute hydrochloric acid, and is very sonorous. Dale gives the constituents of the slate in order of their abundance as muscovite and sericite, quartz, biotite, carbonate, graphite (or carbonaceous matter), pyrite, chlorite, magnetite, with accessory plagioclase, zircon, hematite, tourmaline, and rutile.

Although Dale's results on the microscopic study of the Arvonia slate show the presence of some carbonate, an appreciable amount of ferrous carbonate can not be present, for the use of these slates on buildings in Richmond more than 60 years ago, and on buildings near the quarries for more than a century, shows no discoloration whatever. Strength and durability would naturally follow from the highly crystalline character of this slate.

The Arvonia belt of slate extends for some distance northeastward across the James River into Fluvanna County, and has been opened at several places in the vicinity of Bremo, Fork Union, and Palmyra. Some recent prospecting of the slate in the vicinity of Fork Union and Palmyra, by the Old Dominion Slate and Cement Company, gave most encouraging results as to quantity and quality of the slate, and it is expected that systematic quarrying by this company will be begun at an early date.

About 20 miles west-northwest of the Arvonia belt is the Keswick-Esmont slate belt. It has been prospected at several places, and quarries producing an excellent grade of slate are operating in the vicinity of Esmont.

The Snowden slate belt occurs on the southeast side of the Blue Ridge, in the vicinity of Snowden station, in the southwest part of Amherst County. The belt has been prospected in a number of places, and the Williams Bros. Slate Company has successfully operated a quarry about three miles north-northwest of Snowden. The slate strikes N. 65° E., and has quartzite southeast of it which has been referred to the Cambrian. The cleavage strikes N. 45° E. and dips S. 60° E., and is cut by the original bedding planes which are quite strongly marked at an angle of 45° and more. The slate is very dark gray, has a minutely granular texture, moderately smooth cleavage, but with little lustre. It resembles the Arvonia slate in not effervescing with cold dilute hydrochloric acid and in being quite sonorous, but differs from it in not being graphitic nor magnetitic. Arranged in order of abundance, the chief constituents are, according to Dale, muscovite (sericite), quartz, chlorite, kaolin, pyrite, carbonate, rutile, and carbonaceous matter. It is used exclusively for roofing and is a superior slate, though less crystalline than the Arvonia slate.

In Fauquier and Culpeper counties, slate outcrops are traceable to the north and south of the Rappahannock River in the vicinity of White Sulphur springs. The slate outcrops about one mile south of the springs, and is traced northward for a distance of two miles, with a minimum width of half a mile. The strike of the cleavage over most of the belt is N. 25° to 30° E., with a change in strike to an east-westward direction about three-quarters of a mile south of the springs. The slate is black, of moderately fine texture, and has but little lustre. It is very carbonaceous, shows much pyrite in places, contains no magnetite, does not effervesce with cold dilute hydrochloric acid, and has an argillaceous odor. In the northeasterly opening, Dale gives the chief constituents of the slate, arranged in the order of abundance, as carbonaceous matter, quartz, muscovite, feldspar, pyrite, and chlorite.

Investigations of this belt by the State Geological Survey indicate that pyrite is not present in harmful quantity in all parts of the belt, but that important commercial slate is found, and was quarried on a small scale from a number of openings many years ago, and used locally for roofing purposes.

In Prince William, Stafford, and Spottsylvania counties is one of the most extensive belts of slate in the State. This has been named the Quantico belt by Darton, from the creek by that name. No developments have been made on this belt, and it is not known whether it contains slate of commercial grade or not, but it is being carefully investigated by the State Geological Survey.

The total production of slate in Virginia during 1909 amounted to 40,880 squares, valued at $180,775, as against 41,678 squares, valued at $194,356 in 1908, a decrease of 798 squares in quantity and $13,581 in value. The 1910 production amounted to 31,787 squares, valued at $148,721. These figures when compared with the 1909 production represent a decrease of 9,093 squares in quantity and $32,054 in value. In 1910, there were seven producers of slate operating in two counties, namely, Albemarle and Buckingham, with the principal part of the production from Buckingham County. The amount and value of the annual production from 1903 to 1910, inclusive, are given in the accompanying table:

Production of Slate in Virginia, 1903-1910.

Year	Roofing Slate Number of Squares	Value	Average Price Per Square
1903	29,646	$115,356	$3.89
1904	31,852	130,208	4.08
1905	86,102	146,786	4.07
1906	39,068	172,857	4.42
1907	37,172	173,670	4.68
1908	41,678	194,356	4.66
1909	40,880	180,775	4.42
1910	31,787	148,721	4.68

The number of squares, as given in the above table, includes both first and second qualities, and the average price per square does not give a fair indication of the prices obtained for most of the stock.

LIST OF SLATE OPERATORS

OPERATOR	OFFICE	QUARRY
Arvonia Slate Co., Inc	Lynchburg	Arvonia
Buckingham Slate Co., Inc	Richmond	Arvonia
Carbolane Slate Co	Esmont	Esmont
Ferncliff Slate Co	Rochester, N. Y.	Arvonia
James River Slate Co	New Haven, Conn	New Canton
LeSeuer Slate Co., Inc	Orebank	Orebank
Old Dominion Slate & Cement Co	Palmyra	Palmyra
Penlan Slate Co	Penlan	Penlan
Pitts, A. L	Arvonia	Arvonia
Richmond Slate Co., Inc	Richmond	Arvonia
Standard Slate Corporation	Esmont	Esmont
Victory Buckingham Slate Co	Penlan	Penlan
Virginia Slate Co., Inc	Arvonia or Farmville	Arvonia
Williams Bros. Slate Co	Snowden	Snowden
Williams Slate Co	Arvonia	Arvonia

CRUSHED STONE.

The state-wide interest in good roads construction and improvement, and in the building of new lines of railway in Virginia during the past year, have greatly increased the demand for crushed stone. This material is used exclusively for road-making, railroad ballast, and concrete. The value of the production of crushed stone in Virginia in 1909 was $470,897 and in 1910, $474,430, as compared with $298,614 in 1908.

Road Materials.—The road-building materials of Virginia are abundant and vary greatly in character. Nearly all varieties of stone used in highway construction are found in quantity in many sections of the State. The question of transportation is so important a factor that usually the best materials for road making can not be used in areas far removed from the sources of supply.

In Western Virginia—the Mountain province west of the Blue Ridge—limestones, sandstones, and shales are the principal rocks. Of these, limestone is the best suited for road making. It is found in quantity over most of the region, is easily worked, has good cementing or binding quality, but does not possess the durability of the igneous rocks when used as road metal.

In Middle Virginia—the crystalline area or Piedmont Plateau—the rocks are largely crystalline metamorphic igneous and sedimentary types. These comprise granite, gneiss, schist, and the basic igneous types commonly known as trap, with local areas of slates, limestones, and quartzites. Of these, and in fact of all rocks, the basic igneous types, known as trap, make the best road metal. These rocks are tough and difficult to work, possess a high cementing value, great resistance to wear, and afford a valuable and permanent road metal. These rocks are widely distributed, occurring in practically every county in the Piedmont region.

In Eastern Virginia—the Tidewater or Coastal Plain province—the rocks are of comparatively recent geologic age (late Mesozoic and Cenozoic), and consist chiefly of unconsolidated beds of sand, gravel, clay, and marl, which may be locally indurated by a cement either of iron oxide or carbonate of lime. The gravels and marls, when properly used, are of value in road construction, but they afford a less permanent road metal than the igneous rocks. The oxide of iron and carbonate of lime act as the cementing materials.

Ballast and Concrete.—With the exception of the marls, the materials used for railroad ballast and concrete are the same as those employed in road construction. The requirements are somewhat different from those of good road metal, since little or no binding power is required in railroad ballast, and cementing material is added in concrete.

The value of crushed stone produced in Virginia from 1903 to 1910, by years, is given in the table below.

Value of Annual Production of Crushed Stone in Virginia, 1903-1910.

Year	Granite, Gneiss, Etc.			Limestone			Total
	Road	Ballast	Concrete	Road	Ballast	Concrete	
1903	$31,785	$ 17,400	$ 60,820	$ 300	$16,205	$ 9,238	$135,748
1904	12,940	61,352	165,043	210	32,371	5,668	277,584
1905	21,175	69,360	166,364	5,254	9,333	11,187	282,673
1906	34,981	64,386	85,077	160	16,050	18,700	219,354
1907	59,937	50,804	167,960	37,000	12,269	32,326	360,296
1908	21,670	92,895	81,745	30,159	45,541	26,604	298,614
1909	74,054	125,704	147,112	31,076	84,883	8,068	470,897
1910	40,691	111,811	156,894	20,056	108,129	36,849	474,430

FURNACE FLUX.

Limestone, used in smelting operations for flux, is quarried and shipped to the numerous blast furnaces in the State. The utilization of limestone as flux constitutes the largest consumption of the Virginia stone. Each of the principal limestone horizons in western Virginia supplies some stone as flux to the iron furnaces, but the Cambro-Ordovician and Lewistown (Helderbergian) limestones are the principal sources of stone for this purpose. Of the total production of limestone in the State in 1909, 62.29 per cent was sold as flux and utilized in the blast furnaces, and in 1910, 62.44 per cent was sold for the same purposes. Table on page 80 shows the total value of the limestone production in Virginia for all uses in 1909 to be $342,656, of which $213,444 was the total value of limestone used as flux. The 1910 production of limestone was valued at $471,903, of which $294,668 worth was used as flux.

There are given in the table below the annual production and value of limestone as furnace flux in Virginia from 1902 to 1910, inclusive.

Production of Furnace Flux in Virginia, 1902-1910, in long tons.

Year	Quantity	Value
1902	565,704	$ 220,001
1903	499,108	199,989
1904	273,826	117,882
1905	393,662	186,676
1906	467,341	219,707
1907	541,610	275,517
1908	290,487	169,847
1909	388,746	213,444
1910	540,264	284,668

ABRASIVE MATERIALS.

Under this head are included corundum, emery, and millstones, but in 1909 and 1910 the only abrasive material produced was millstones, which were quarried in Montgomery County.

Corundum and Emery.

The occurrence of corundum and emery has been noted in Virginia, but neither has been produced on a commercial scale.

Corundum.—The principal occurrence of corundum is in Patrick County, about two miles from Stuart, where it occurs on a knob of Bull Mountain, in mica schists. It is a grayish-white to white and colorless and, according to Pratt, is readily cleaned. Tests made for the cleaned product at this locality show that the corundum is well adapted to the manufacture of the vitrified wheel.

Emery.—Emery, a granular corundum of black or grayish-black color and containing magnetite or hematite intimately mixed, is found in considerable quantity a short distance west of Whittles in Pittsylvania County. Two openings about 300 feet apart and 20 feet deep have been made on apparently parallel "veins." Numerous smaller openings have been made near by. The rocks inclosing the emery are probably altered amphibolites or pyroxenites.

Millstones (Buhrstones).

Under this name is included a siliceous conglomerate of quite variable structure, used in the form of flat-circular disks for grinding purposes.

About five miles west of Blacksburg, in the vicinity of Prices Fork, Montgomery County, a sandstone-conglomerate occurs in Brush Mountain, in which quarries have been opened for a distance of three miles. The rock is somewhat variable in color, but is usually of some light shade, white or gray. Likewise variation in the size of the pebble is shown. The rock is made up of well-rounded pebbles of quartz compactly imbedded in a fine siliceous sandstone matrix, the whole forming an exceedingly tough and hard mass. This rock is known on the market as "Brush Mountain" stone. Practically the same variation in the sizes of stone made at the different quarries obtains. The sizes of stone produced in 1910 as reported to the State Survey office were, 12, 14, 16, 20, 24, 26, 30, 36, 42, 48, and 54 inches.

The grindstones made from this rock are of excellent quality and find a ready market. The geologic age of the "Brush Mountain" stone is Mississippian (Lower Carboniferous).

Similar siliceous conglomerates occur in other counties of the State, especially in some of the counties of the Mountain province, but the Brush Mountain quarries, in Montgomery County, are the only producing ones.

The production of millstones in Virginia during 1909 was valued at $12,348, as against $7,954 in 1908, an increase in value of $4,394, or 55.5 per cent. The value of the millstone production for 1910 amounted to $5,273, a decrease of $7,075, or nearly 57.3 per cent in comparison with the figures for 1909. The value of millstones produced in Virginia for the years 1902 to 1910, inclusive, follows below in tabular form.

Value of Millstones Produced in Virginia, 1902 to 1910, inclusive.

Year	Value
1902	$ 11,435
1903	9,812
1904	4,759
1905	8,186
1906	15,611
1907	4,684
1908	7,954
1909	12,348
1910	5,273

LIST OF ABRASIVE OPERATORS

OPERATOR	OFFICE	QUARRY
Olinger, R. L	Prices Fork	Brush Mountain, near Prices Fork
Price, A. S	Prices Fork	
Price & Co., B. S	Prices Fork	
Price & Son, Z	Blacksburg	
Standard Millstone Co	Vicar Switch	

SILICA.

Under this heading are included three forms of silica which have rather wide distribution in the State. These are quartz, chert, and diatomaceous earth.

QUARTZ.

Quartz has wide distribution in the State. It occurs as an essential constituent in granite, gneiss, and mica schist of the crystalline area; as the dominant constituent in the sandstones, quartzites, and conglomerates of the Piedmont and Valley regions; and in the form of sand over parts of each of the larger geologic divisions of the State. A principal occurrence of quartz in Virginia, that is of commercial value, is in the form of pegmatite dikes and quartz veins penetrating the older metamorphic rocks of the Piedmont region.

There was no reported production of quartz in 1909 and 1910.

CHERT.

Chert, known also as hornstone, a term applied to any impure flinty rock, including the jaspers, is a chalcedonic variety of silica. Chert has wide distribution in certain beds of the Shenandoah or Valley limestone of the Valley region, in the form of irregular nodular masses of light nearly white, red, brown, and black colors. No special use has yet been made of the Virginia chert.

DIATOMACEOUS EARTH.

Diatomaceous earth, known in the trade under the name of "silica," "infusorial earth," or "tripoli," is composed of minute shells or tests of microscopic plants known as diatoms. It was first reported from the vicinity of Richmond, Virginia, and for that reason received the name of "Richmond earth," under which term it is sometimes referred to in the literature. Because of its occurrence at Bermuda Hundred, on the James River, it has also been called "Bermuda earth."

The first bed of diatomaceous earth of any extent discovered in this country was in the Richmond area. It is known as the Richmond bed, which extends from Herring Bay on the Chesapeake, Maryland, to Petersburg, Virginia, and probably beyond. It is not less than 30 feet in thickness in places, though very impure at times. It is of Miocene age, and is exposed along the numerous streams close to their crossings from the crystalline rocks on to the sediments of the Coastal Plain.

The diatomaceous earth has been dug from time to time in the vicinity of Richmond for commercial use. There has been no reported production of this material in Virginia for several years.

MICA.

Commercial mica, which includes the varieties known as muscovite and phlogopite, usually occurs in pegmatite dikes penetrating granites, gneisses, and schists. The pegmatites usually consist of a coarse crystallization of quartz and feldspar in varying proportions, with or without mica, and other accessory minerals. They vary in thickness from a few inches to several hundred feet, are often irregular in outline, and may be parallel to or break across the schistosity of the inclosing rocks. In small veins the mica is frequently too small in size to have commercial value. Both the quartz and the feldspar of the pegmatites are of value, and are sometimes mined with the mica and utilized in the manufacture of pottery and for abrasives.

Pegmatites containing commercial mica are somewhat abundantly developed in many of the Virginia Piedmont counties, and many excellent surface indications for mica occur, but as yet prospecting and mining have been confined to only a few of them. Mica has been either prospected or mined in the following counties in Virginia: Near Amelia and Jetersville, Amelia County; near New London and at Lowry, Bedford County; Goochland County; near Chatham, Pittsylvania County; near Axton and at Ridgeway, Henry County; near Hewlitts, Hanover County; near Farmville and at Prospect, Prince Edward County; Amherst and Charlotte counties. Indications of mica occur also in Buckingham, Caroline, Cumberland, Franklin, Powhatan, and Spottsylvania counties.

The mica of the Amelia County district occurs in pegmatites cutting a thinly foliated, biotite gneiss, which, in places, shows a distinct "augen" texture. The proportion of mica, quartz, and feldspar in the pegmatites is quite variable. The feldspar varieties include orthoclase, microcline, and albite. A considerable number of accessory rare minerals have been found in the Amelia pegmatites, and some of them have been used for gems. More than a half dozen mines have been opened in the county, but the Pinchbeck and Schlegal mines are the only ones that have been worked for mica in recent years.

The mines owned by the Hanover Mica Company, near Hewlitt, in Hanover County, were the first mines worked for mica in Virginia. These were first worked from 1867 to 1870 by Barr, Johnson and Company, of Erie, Pennsylvania, with a production of more than 60,000 pounds of clipped stove mica. Regular mining has not been engaged in within recent years, although about 1,000 pounds of rough mica of excellent grade and clear white color were worked from the mines during the fall of 1907. Some of this was reported to be about 18 by 33 inches in size.

The Pittsburg Mica Company's mine at Ridgeway, Henry County, was developed by an open cut about 100 feet long and 40 feet deep, and much cross-cut work. The plant completed at the mine in 1907 was destroyed by fire in 1908, which greatly curtailed the production of mica by the company for that year.

The production of mica in Virginia during 1909 was 7,833 pounds of sheet mica and 75 tons of scrap, with a total valuation of $4,600, and was obtained from three producers. There was no production of mica reported in 1910.

LIST OF MICA OPERATORS

OPERATOR	OFFICE	MINE
American Asbestos Co.	Terre Haute, Ind.	Bedford City
Cole, A. L.	Chatham	Chatham
Corson, F. W.	Waymart, Pa	Amelia
Corson Mica Co., Inc.	E. Stroudsburg, Pa	Amelia
Hanover Mica Co.	Hewlett	Hewlett
Henry Mica Corporation	Columbus, Ohio	Martinsville
Mecklenburg Mica & Mining Co.	Petersburg	Petersburg
Otto Hill Mica Mines	Findlay, Ohio	Bedford City
Patterson, J. M.	Washington, D. C.	Amelia County
Pinchbeck Mica Mines	Chula	Amelia Courthouse
Roanoke Mica Mining Co.	Francisco, N. C.	Roanoke
Watton & Fontaine	Axton	Martinsville

FELDSPAR.

The feldspar group includes a number of mineral species, which chemically are silicates of aluminum with varying amounts of lime, and the alkalies, potash and soda. Of the nine known species of feldspar only a few are of commercial value, the principal ones being the potash varieties, orthoclase and microcline, and the soda variety, albite. Orthoclase or microcline, or an intergrowth of these two, are the species most commonly used by potters in this country. The potash feldspars are frequently associated with small quantities of the soda feldspar, albite, which occurs either as separate crystals or intergrown with the orthoclase or microcline.

Commercial feldspar usually occurs associated with quartz and mica as coarse crystallizations in pegmatite dikes, cutting granites, gneisses, and crystalline schists. Pegmatites are rocks usually of extreme coarseness and of irregular texture and composition. Dikes of pegmatite containing feldspar as an important constituent are quite widely distributed throughout the Virginia Piedmont region, hardly a county within the region being without them. Notwithstanding the abundance of these dikes in the Virginia Piedmont province, many of which contain commercial feldspar, the attempts to mine the mineral are comparatively few, and as yet the production is small and variable. Feldspar has been mined in Amelia, Bedford, Hanover, Henry, and Prince Edward counties. In a majority of these counties feldspar has been mined with the associated mica of the pegmatites.

In order to avoid disclosing individual figures, the production of feldspar in Virginia for the years 1909 and 1910 is combined with that of another subject.

LIST OF FELDSPAR OPERATORS

OPERATOR	OFFICE	MINE
Bedford Spar Co.	Roanoke	Bells
Dominion State Mines Corporation	Farmville	Prospect
Patterson, J. Murrell	Washington, D. C.	Amelia County
Pinchbeck, W. L.	Chula	Amelia
Schlegal	Jetersville	Jetersville

ASBESTOS.

Prior to 1907, Virginia was a producer of asbestos for a number of years. No production has been reported during the last four years. The mineral has been noted in a number of the Piedmont counties, and it has been mined in Amelia, Bedford, and Franklin, principally the two latter. The mines have been inactive since 1906 and the mill at Bedford City for fiberizing the asbestos is closed, though there is a probability that it will be in operation again in the near future.

In Bedford County, the mines of the American Asbestos Company are located near Chestnutfork post-office, about 12 miles south of Bedford City, on the Hubbard farms. According to Diller[a], the asbestos rock is of two types. The first type is like that of Sall Mountain, Georgia, and is composed essentially of fibrous amphibole, the fibers of which are arranged in groups or bundles lying in all directions, and is derived from pyroxenite. The other type is a peridotite composed chiefly of granular olivine, with numerous acicular crystals and fibrous bundles of anthophyllite. Diller[b] states that this type is cut by a few small veins of cross-fiber anthophyllite, one-eighth to three-quarters of an inch in length. The fiber is flexible, somewhat elastic, has numerous cross fractures, and is relatively short and brittle. The asbestos mined occurs as vein-like masses of slip fiber, lying parallel to the plane of slipping, which cut the rock as occasional planes of shearing. These masses are very irregular, locally 18 inches thick, and along the strike have a length of about 30 feet.

In Franklin County, a small amount of asbestos was recently mined from a 40-foot shaft a short distance east of Rocky Mount. The asbestos-bearing rock[c] is amphibolite, which locally contains some olivine, and is much altered to chlorite and serpentine. The asbestos is found in a vein which lies parallel to the schistosity of the inclosing amphibolite, with strike S. 50° E. and steep dip to the northeast. The principal constituent is probably tremolite.

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[a] Diller, J. S. Mineral Resources of the United States, Part II, Nonmetallic Products, 1907, p. 718.

[b] Ibid., pp. 718-719.

[c] Ibid., p. 719.

LIST OF ASBESTOS OPERATORS

OPERATOR	OFFICE	MINE
American Asbestos Co.	Terre Haute, Ind.	Chestnutfork
Heermance, E. Van Ness	New York, N. Y.	Rocky Mount
Hubbard, L. F.	Body Camp	Body Camp
Pine Mountain Mica & Asbestos Co.	Richmond	
Smithers, W. C.	Rocky Mount	Rocky Mount

TALC AND SOAPSTONE.

Virginia is by far the most important state in the United States in the production of soapstone, which has wide distribution over the Piedmont region. It has been noted in the following counties: Albemarle, Amelia, Amherst, Bedford, Buckingham, Campbell, Carroll, Charlotte, Fairfax, Floyd, Fluvanna, Franklin, Grayson, Henry, Louisa, Nelson, Patrick, and Stafford. Many of the deposits are of excellent grade, and the stone has been quarried on a commercial scale in at least six of the above-named counties; but practically the entire production in Virginia at present comes from the Nelson-Albemarle counties belt.

In Fluvanna and Buckingham counties, soapstone was quarried many years ago on a small scale near the mouth of Hardware Creek, and the product used locally for hearths, jambs, and other parts about chimneys. It has also been made use of further east in the southern part of Fluvanna County, at Bremo, and a good grade of it occurs at several localities in the vicinity of Palmyra.

In Albemarle County, a little west of Green Mountain, is a belt of soapstone associated with quartzites and micaceous schists, which is traced southwestward through Nelson into Campbell, Bedford, and Franklin counties. The belt widens in Nelson County and is associated with some serpentine. It passes thence as a narrow belt along the western base of Buffalo Ridge, in Amherst County, crossing the James River above Lynchburg, and is exposed about two miles west of the city on the road leading to Bedford City, and is exposed again two and a half miles west of New London in Bedford County. Continuing in the same direction, the stone is seen again at the meadows of Goose Creek, where it has been quarried to some extent. Continuing still further westward, it is exposed in several nearly parallel belts, of which the most eastern makes its appearance near Pig River in Franklin

County. A second belt occurs in the same vicinity near the eastern base of Jack's Mountain; a third still further west about one mile from Rocky Mount; and a fourth yet more to the west on the eastern slope of Grassy Hill. The stone has been quarried in a small way at several places in Franklin County, near Rocky Mount, and used strictly for local purposes. Extensive quarrying operations are in force in the Albemarle-Nelson counties' portion of the belt, which is described below.

In Amelia County, south of Chula, and about four miles from Amelia, soapstone of good quality was quarried quite extensively many years ago. A second more extensive area of soapstone of excellent quality occurs on the north side of Flat Creek, about four and a half miles north of Jetersville. On the headwaters of Walnut Creek, a tributary to Flat Creek, soapstone has been quarried to some extent. Quarrying was begun in 1904, and during the summer of 1906 numerous other smaller openings were made nearby. This property is controlled by the Tip Top Soapstone Company, and much preliminary work was in progress during 1908 preparatory to systematic quarrying in 1909.

In Louisa County, soapstone of good quality is reported to have been quarried near Oakland and Trevilians.

In Fairfax County, soapstone occurs two miles east of Annandale, one mile east of Tenley, and east of Falls Church. In each of these localities, the soapstone occurs as lenticular bodies closely associated with basic eruptive rocks, and were probably derived from peridotite and pyroxenite. All of these bodies have been worked to some extent, and in the Annandale area much stone has been quarried and sawed. The stone is of good quality, even-grained, and of uniform light bluish-green color, without seams and schistose planes developed in it. Small quarries of soapstone are operated in Fairfax County, near Clifton and Wiehle. At the former, soapstone is ground, but at Wiehle it is sold in the crude state just as it is taken from the quarry.

In Henry County, near Spencer's store, quarries of soapstone were opened some years ago. The material was of excellent quality, and blocks of any required dimensions were reported to have been ıarried. These were sawn out and then finished by planing. They ›re used in the foundations of houses and for other purposes.

In Albemarle and Nelson counties, the soapstone belt is a short stance west of Green Mountain, and, to the east, near and approxiately parallel to, Hawkins, Finley, Ball, and Appleberry mountains. has a general northeast-southwest direction, and is three to five miles utheast of the main line of the Southern Railway, which it roughly .rallels. Quarries have been opened on the belt at numerous points r a distance of nearly 30 miles. Several of the most extensively ›rked quarries have reached depths of more than 120 feet. The rger quarries are well equipped with all necessary modern machinery r getting out the stone, including channeling machines for quarrying e rock, and at each quarry is a mill for sawing, dressing, rubbing, ıd polishing the stone, and other machines for grooving and drilling ›les. The excellent quality of this stone adapts it to a wide range of ›es, the principal ones including laundry tubs, sanitary purposes, ›ctrical purposes, sinks, and cooking utensils.

In Stafford County, soapstone of good quality occurs near Garrinville.

The production of talc and soapstone in Virginia during 1909 owed a marked increase over that of 1908. The figures were 26,511 ort tons, valued at $523,942, as compared with 19,616 short tons, .lued at $458,252 in 1908, an increase in quantity of 6,895 tons, .d in value of $65,690, or 14.3 per cent. The 1909 production was ›tained from 11 producers, operating in five counties, namely, Nelson, airfax, Albemarle, Amelia, and Campbell. Only a small proportion the total quantity of talc and soapstone quarried in Virginia is sold the crude state. The talc and soapstone production is classified in e following four groups: Rough or crude, sawed into slabs, manuctured articles, and ground.

The production of talc and soapstone in Virginia during 1910 nounted to 25,908 short tons, valued at $510,781, as compared with ›,511 short tons, valued at $523,942 in 1909. These figures represent decrease in quantity of 603 tons, and in value of $13,161, or 2.5 ›r cent. The 1910 production was obtained from 9 producers operatg in four counties, as against 11 producers operating in five counties during 1909. Although there was a decline in the total production, practically half of the quarries operating increased in production. The 1910 production was from the four following counties: Albemarle, Campbell, Fairfax, and Nelson. Of the total production, 1,388 tons were sold as crude talc, and 2,502 tons were sold in the form of slabs. More than 82 per cent of the production was sold as manufactured products, chiefly as laundry tubs.

In the following table are given the quantity and value of talc and soapstone produced in Virginia during the years 1909 and 1910, according to the condition in which it was marketed.

Production of Talc and Soapstone in Virginia during 1909 and 1910, according to varieties.

	1909		1910	
	Quantity Short tons	Value	Quantity Short tons	Value
Rough Ground[a]	2,150	$ 9,450	2,108	$ 8,364
Sawed into slabs	2,868	53,859	2,502	47,542
Manufactured articles[b]	21,493	460,633	21,298	454,875
Total	26,511	$523,942	25,908	$510,781

[a] For paint, paper filling, complexion powders, lubricants, etc.

[b] Includes washtubs, laboratory or kitchen sinks, stove bricks, griddles or other mill stock.

There is given in the table below the yearly production of talc and soapstone in Virginia from 1905 to 1910, inclusive:

Production of Talc and Soapstone in Virginia, 1905-1910, in short tons.

Year	Quantity	Value
1905	17,665	$425,090
1906	23,624	590,800
1907	26,278	631,880
1908	19,616	458,252
1909	26,511	523,942
1910	25,908	510,781

LIST OF TALC AND SOAPSTONE OPERATORS

OPERATOR	OFFICE	QUARRY
Austin Run Mining Co	Philadelphia, Pa	Garrisonville
Bull Run Talc & Soapstone Co	Clifton Station	Clifton Station
Climax Soapstone Co	New York, N. Y., or Elmington	Elmington
Cuthbert Land & Development Co	Wiehle	Wiehle
Eureka Soapstone Co	Shipman	Shipman
Fairfax Soapstone Co	Wiehle	Wiehle
Gilmore, W. J	Louisa	Louisa
Hester Estate, B. H., W. S. Buchanan, Mgr.	Trevilians	Trevilians
Hutchinson, H. B	Washington, D. C	Shipman
National Soapstone Co	New York, N. Y	Wiehle
Old Dominion Soapstone Corporation	Esmont	Damon
Otter River Stone Co	Bramwell, W. Va	Lynch Station
Phoenix Soapstone Co	New York, N. Y	Arrington
Piedmont Soapstone Co	Boston, Mass	Asbestine
Pinkerton, W. A	Alberene	Alberene
Tip Top Soapstone Co	Philadelphia, Pa	Jetersville
Virginia Soapstone Co	Schuyler	Alberene and Schuyler

BARYTES.

Barytes has been mined for many years in various parts of the State. It occurs in many counties, but the industry has been confined to only a few of them. The counties in which it is found are: (1) those east of the Blue Ridge in the crystalline area, and include Amherst, Bedford, Buckingham, Campbell, Fauquier, Louisa, Nelson, Orange, and Prince William; and (2) those counties west of the Blue Ridge, and comprise Bland, Botetourt, Frederick, Montgomery, Rockbridge, Russell, Scott, Smyth, Tazewell, Warren, Washington, and Wythe. Of these, Bedford, Campbell, Pittsylvania, and Prince William counties, of the Piedmont province, and Russell, Smyth, and Tazewell counties, of the Mountain province, have practically yielded the entire production of the State.

Geologically, the barytes deposits found in the Piedmont region are associated either with the crystalline metamorphic rocks (limestone, chiefly) of probable Cambrian age, or with the Triassic red shale-sandstone series, and those of the Mountain region are usually associated with the Shenandoah limestone of Cambro-Ordovician age or its residual decay.

In the Triassic area of Prince William County, barytes mined about four miles south of east from Catlett is associated with red shale and impure limestone, usually filling fractures of variable width in the red shale, and in thin, tabular, cleavable masses in the limestone. During 1908, deposits of barytes of good quality and in quantity are reported to have been opened in the vicinity of Bealton, Fauquier County.

In the crystalline area, the principal production of barytes has been from Campbell, Bedford, Louisa, and Pittsylvania counties. The Campbell-Pittsylvania counties area is traced for a distance of about 50 miles southwestward, beginning in the middle western portion of Campbell County, several miles east of Evington, and about 15 miles south of Lynchburg to three or more miles south of Sandy Level, in the northwestern part of Pittsylvania County. The most extensively worked deposits in this area are grouped about two centers, Evington, in Campbell County, at the northeast, and Toshes and Sandy Level, in Pittsylvania County, at the southwest extremity of the area.

The barytes in the extreme northwest corner of Pittsylvania County has been more extensively worked than in any other part of the belt. It has been developed by a large number of mines, grouped in two nearly parallel belts on either side of Pig River, just south of its entrance into Roanoke River.

Numerous openings have been made at different points on the belt between the two centers mentioned above, many of which have been extensively worked and have produced large quantities of excellent ore. The barytes occurs in the Campbell-Pittsylvania counties belt in intimate association with the crystalline limestone as irregular lenticular bodies or pockets, which measure from 100 to 200 feet or more, replacing the limestone. For the depths thus far attained in mining, there is immediately above and below the limestone, a variable thickness of a nearly black clayey mass, usually preserving the foliation of the original rock from which it was derived, and colored black from manganese oxide. Through this black clayey mass are usually distributed, in irregular fashion, lumps and nodules of barytes of large and small sizes.

Near Thaxton, in Bedford County, barytes occurs filling a fracture in a foliated granite of coarse grain. About three miles south of east from Lindsay, in Louisa County, barytes has been mined from a number of test pits and several shafts. The barytes occurs in pockets having a thickness of about three feet where worked, and probably represents a filling of an irregular fracture in the crystalline schists.

In southwest Virginia, the barytes is found in association with the Shenandoah limestone or its residual decay. It fills in part, at least, fractures in the limestone, and in part it replaces the limestone. In the clay derived from the weathering of the limestone, the barytes is found in nodules of large and small size irregularly distributed through the clay.

The production of barytes for the years 1909 and 1910, respectively, can not be published separately without disclosing individual figures, hence it is combined with another subject. There were two active producers in Virginia in 1910, and the production of refined barytes was reported by one mill.

The following table gives the quantity, total value, and average price per ton of the barytes produced in Virginia from 1902 to 1908.

Production of Crude Barytes in Virginia, 1902-1908, in short tons.

Year	Quantity	Value	Average price per ton
1902	12,400	$39,700	$3.20
1903	5,700	20,400	3.58
1904	11,214	31,452	2.84
1905	6,468	27,838	4.30
1906	11,775	45,336	3.85
1907	9,254	32,833	3.55
1908	3,866	17,572	4.55
1909	(a)	(a)	
1910	(a)	(a)	

[a] Combined with another subject in order to conceal figures of production, there being only two producers during the years 1909 and 1910.

LIST OF BARYTES OPERATORS

OPERATOR	OFFICE	MINE
Berg, Henry	Verona, Pa	Richland
Clinch Valley Barytes Co	Honaker	Honaker
Langhorne, R. H	Evington	Evington
Marks, S. B	Leesville	Leesville
Nulsen, Klein & Krausse Manufacturing Co	St. Louis, Mo	Toshes
Pittsburg Baryta & Milling Corporation	Pittsburg, Pa	Russell and Tazewell counties
Williams & Son, John T	Bristol, Tenn., or New York, N. Y.	Roanoke County (?)

GYPSUM.

Commercial deposits of gypsum in Virginia occur associated with salt in Washington and Smyth counties, in the valley of the North Fork of the Holston River. They are associated with rocks of Mississippian (Lower Carboniferous) age. They are limited to the narrow belt on the northwest side of the Saltville fault, included between the fault and the Carboniferous shales and sandstones of the basal slopes of Pine and Little Brushy mountains. So far as has been made out, this narrow belt is composed of the Greenbriar limestone (Lower Carboniferous), and the beds of salt and gypsum.

Gypsum of excellent quality has been mined at numerous points in the Valley between Plasterco and within three miles west of Chatham Hill. The mines of the United States Gypsum Company at Plasterco, Washington County, and the Southern Gypsum Company, three and a half miles northeast of Saltville, Smyth County, are the most extensive in the valley and were the only ones that produced in 1910. The production of gypsum in Virginia in 1909 is included under "Other products" in table on page 5, in order to avoid disclosing individual production, since there were only two producers. The 1910 production of gypsum is included under the same heading in table on page 6.

An underground examination of the gypsum, in the openings at Plasterco, indicates the occurrence of gypsum with much admixed anhydrite in huge boulder masses, in gray and red clays. Both clays are abundant, the red being softer than the gray and is utilized to some extent in the manufacture of plaster. The gypsum as mined is ground and calcined at the milling plant located at the mines, and the product is used chiefly as calcined and wall plasters, and as land plaster.

The Southern Gypsum Company began prospecting on its property, three and a half miles northeast of Saltville, in the summer of 1906. After nearly a year of drilling, the company demonstrated a large supply of gypsum and erected a mill with the capacity of 400 tons per day. The product of this company is put upon the market chiefly in the form of wall plaster and land plaster.

LIST OF GYPSUM OPERATORS

OPERATOR	OFFICE	MINE
Buchanan, D. J. & W. W.	Chatham Hill	Chatham Hill
Southern Gypsum Co., Inc.	North Holston	North Holston
U. S. Gypsum Co.[a]	Chicago	Plasterco

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[a] Formerly Buena Vista Plaster and Mining Co., Plasterco.

SALT.

Salt brines and rock salt occur in the Holston Valley of southwest Virginia in association with gypsum. The salt and gypsum deposits are confined to a narrow northeast-southwest valley of the North Fork of the Holston River, extending from Plasterco to within three miles of Chatham Hill, a distance of about 16 miles. The interbedded salt and gypsum shales with beds of rock salt and gypsum are regarded as of Mississippian (Lower Carboniferous) age.

A shaft was sunk in 1840 which struck a bed of rock salt at a depth of 210 feet. A large number of wells have been bored, ranging in depth from 300 to 1,400 feet, the greatest depth reached being 2,380 feet. The first borings for salt in this valley were in the old swampy lake-covered area near the present site of the town of Saltville. Mining of the rock salt has not been attempted, the entire salt product being derived from the salt brines of the wells. The entire salt industry at present is confined to the immediate vicinity of Saltville, and is controlled by the Mathieson Alkali Works.

In the early history of operations and, indeed, until within recent years, the product marketed was salt, which for many years amounted to between a half million and a million bushels of salt per year. The Mathieson Alkali Works stopped the making of salt in 1903, and from that time until 1908 the brines were utilized exclusively for the manufacture of sodium carbonate and caustic soda. The product was of superior merit from the start, and, because of this fact, a large and growing trade has been acquired. The manufacture of salt was again resumed in 1908 by the company, but, since there was only one operator, the figures of value of the production had to be combined with those of another subject, in order not to disclose private business. The same condition holds in respect to the production for the years 1909 and 1910, hence the figures are combined with those of another subject.

MINERAL PAINTS.

Ocher of more or less purity is found, and has been mined to some extent in each of the principal geologic divisions of the State, namely, the Coastal Plain, the Piedmont Plateau, and the Valley region. It has been mined at the following localities in Virginia: In the extreme eastern part of Chesterfield County, near Bermuda Hundred, on the Appomattox River; in the Little Catoctin Mountain, near Leesburg, in Loudoun County; near Bedford City, in Bedford County; near Keezletown, in Rockingham County; from the western base of the Southwest Massanutten Mountain, near Stanleyton, in Page County; and near Shenandoah Station, in Page and Rockingham counties.

In addition to these, ocher deposits are found rather widely distributed over the Valley and Piedmont provinces, and to some extent over the Coastal Plain, which have not been worked. In the Valley and Piedmont provinces, the ocher deposits are frequently associated with beds of iron ore. Deposits of ocher varying in color from red, yellow, and brown, and which seem particularly promising but not yet developed, are found in Campbell and Bedford counties; near Bon Air, in Chesterfied County; near Fairfield, in Rockbridge County; near Waynesboro, in Augusta County; and near Roaring Run, in Craig County. The production of ocher in Virginia during 1909 and 1910 is combined with another subject in order to avoid disclosing individual figures.

LIST OF MINERAL PAINT OPERATORS

OPERATOR	OFFICE	MINE
Bermuda Ocher Co	New York	Bermuda Hundred
Butterworth, R	Butterworth	Pride
Frazer Paint Co	Detroit, Mich	Bedford City
Stigleman, W. T.	Snowville	Snowville
Virginia Ocher Corporation.[a]	Irwin, Pa	Stanleyton

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[a] Formerly Page Ocher Corporation, Stanleyton.

MARL.

Calcareous and greensand marls are widely distributed over the Coastal Plain or Tidewater region of Virginia. Calcareous marls are also found in places in the Valley region west of the Blue Ridge. They have not been developed in Virginia, however, except for local use.

The greensand marl is Eocene in age, and is formed chiefly along the inner margin or western portion of the Coastal Plain, where it is exposed along the Potomac, Rappahannock, Pamunkey, and James rivers. It also occurs on the interstream areas, and has been traced southward from the James River almost to the State line. The greensand marls contain a small percentage of potash and frequently phosphoric acid, the potash content varying according to the quantity of the mineral glauconite present. Shells are usually present in the deposits and supply lime in addition to potash and phosphoric acid. These marls have value as a fertilizer, and have been worked at a number of places on the James and Pamunkey rivers.

The calcareous (shell) marls are abundant over much of the Coastal Plain region, being especially so in the Miocene and, in places, hardly less abundant in the Eocene. The deposits are quite extensive in some localities, and contain as much as 80 to 97 per cent of calcium carbonate in places. In addition to their agricultural value, many of the beds are large enough and of sufficient quality to be used in the manufacture of Portland cement. The State Geological Survey has had under investigation these deposits with a view to their use in Portland cement manufacture, and a plant has been erected at Norfolk by the Norfolk Portland Cement Company for the manufacture of cement from these marls. Charters have been granted the Jamestown Portland Cement Corporation and the Colonial Portland Cement Corporation for the erection of plants and the manufacture of cement from marls and clays at Yorktown and near Grove Station. It is hardly necessary to call attention to the advantages afforded in this region to water transportation.

There was no production of marls in Virginia during the years 1909 and 1910.

PYRITE AND PYRRHOTITE.

The tabulation of production and value of pyrite in Virginia by years, given on page 111, includes both pyrite and pyrrhotite. Virginia has long held the position of first producer of pyrite among the pyrite-producing states in the United States.

Commercial pyrite occurs in Louisa, Stafford, Spottsylvania, and Prince William counties. Mines are opened in each of these counties, but the production has been from Louisa and Prince William counties. The pyrite mines in these two counties are probably the largest and most extensively developed ones in the United States, and the product from them constitutes nearly 50 per cent of the total output of pyrite in the United States.

The pyrite mines in Louisa County were worked at different times for iron, copper, and pyrite. They were first opened and worked for iron in 1834, when the gossan overlying the pyrite for a depth of from 40 to 60 feet was mined for iron-making in the local furnaces. The Prince William County mine, near Dumfries, was first opened in 1889, but was not continuously operated until several years later.

The pyrite deposits in Louisa and Prince William counties occur as lenticular bodies, usually of large size, lying conformable or nearly so with the structure (foliation) of the inclosing rock. The lenses follow each other in the direction of strike, and may or may not be connected by thin and lean stringers of ore. The spacing between the ends of lenses is variable. In a few instances, partial overlap of the lenses has been observed. The lenses vary much in size, those in the Louisa County mines measuring several hundred feet long and as much as 60 to 80 feet in thickness.

As developed by the extensive mining operations, the ore-bodies are marked, in places, by rolls and swells and by pinching and narrowing. The inclosing rocks are metamorphic crystalline schists, chiefly micaceous, with more or less of the minerals, hornblende and garnet, developed in places. The normal rock is a mica-quartz schist, but mica schist without quartz, largely altered to chlorite, quartz-sericite schist, talcose and chloritic schists, and hornblendic schist, occur. Bands and stringers of more or less pure limestone are found in the walls near the ore bodies. Associated with these, is a considerable development of lime-bearing silicate minerals.

The ore consists of the massive-granular type, which varies in texture from very fine- to moderately coarse-grained. Some of it is very hard and non-friable, but much of it is quite friable, and in some mines practically all the ore is of the latter type. Much of the ore is admixed with white granular calcite and some quartz. Chalcopyrite, sphalerite, galenite, pyrrhotite, and magnetite are associated with the pyrite in small quantity. Chalcopyrite is present in sufficient quantity at some mines to warrant the saving of the copper from time to time by precipitation of it from the mine water, when it is dried, screened, and barreled for market. Sufficient chalcopyrite is encountered in the Cabin Branch pyrite mine near Dumfries, in Prince William County, to warrant the building recently of a small smelter for the extraction of the copper.

The principal occurrence of pyrrhotite in Virginia is that of the "Great Gossan Lead" in Floyd, Carroll, and Grayson counties. This "lead" forms a well-defined vein of pyrrhotite varying in width up to 100 feet, and strikes southwestward from Floyd County, through Carroll into Grayson County, a distance of more than 20 miles. It is composed chiefly of pyrrhotite with admixed quartz and schist, and carries streaks and patches of chalcopyrite and pyrite. The vein fills a fault fracture in crystalline schists of unknown age, varies in width from a few feet up to 100 feet, shows a somewhat variable but average dip of about 45°, and has in general an approximate northeast trend. At present, pyrrhotite is mined by the Pulaski Mining Company near Monarat, Carroll County, and the ore treated at Pulaski for sulphur.

The total production of pyrite, including pyrrhotite, in Virginia during 1909, showed a decrease of 2,164 long tons, or 1.86 per cent, in quantity, and $12,239, or 2.81 per cent, in value, in comparison with the figures for the previous year. The production in 1909 was 114,176 long tons, valued at $423,283, as compared with 116,340 long tons, valued at $435,522 in 1908. The average price per ton of pyrite in Virginia during 1909 was $3.71, as compared with $3.74 in 1908. The 1910 production of pyrite showed a considerable increase over the 1909 production, the figures for 1910 being 140,106 long tons, valued at $525,437. It will be seen from these figures that there was an increase over the production for 1909, of 25,930 tons in quantity and $102,154 in value. The average price per ton advanced from $3.71 in 1909 to $3.75 per ton in 1910.

There is given in the table below the production of pyrite in Virginia from 1904 to 1910, inclusive.

Production of Pyrite in Virginia, 1904-1910, in long tons.

Year	Quantity	Value	Average price per ton
1904	120,671	$440,753	$3.65
1905	123,183	426,008	3.46
1906	128,794	431,388	3.35
1907	124,740	372,586	2.99
1908	116,340	435,522	3.74
1909	114,176	423,283	3.71
1910	140,106	525,437	3.75

LIST OF PYRITE OPERATORS

OPERATOR	OFFICE	MINE
Arminius Chemical Co	Mineral	Mineral
Austin Run Mining Co	Philadelphia, Pa	Garrisonville
Braun, Johannes	Passaic, N. J	Green Bay
Cabin Branch Mining Co	Baltimore, Md	Dumfries
Hardy, W. N	Church Road	Iona
Louisa Mining Co	Cuckoo	Mineral (near)
Pulaski Mining Co	New York, N. Y	Monarat
Spottsylvania Sulphur Mines Co	Holladay	Holladay
Sulphur Mining & Railroad Co	Richmond	Mineral
U. S. Fidelity & Guaranty	Baltimore, Md	Mineral
Williams & Son, John T	Bristol, Va.-Tenn	Bonsacks

ARSENIC.

Virginia has not been a producer of arsenic for several years. In 1903, the United States Arsenic Mines Company, of Pittsburg, Pennsylvania, began the mining of arsenopyrite (mispickel) at Brinton, in Floyd County. An extensive plant, erected for refining the product, was started in 1904, with the monthly capacity increased after January, 1905, to 90 tons of pure white arsenic. Operations were temporarily abandoned several years ago, and owing to the low price of white arsenic the Floyd County mines did not operate in 1909 and 1910. A company was organized in 1910 to manufacture Paris green from the white arsenic made at the Floyd County arsenic mine, and a plant was established at Norfolk, Virginia.

The mines are located 14 miles southeast of Christiansburg, at Brinton, Floyd County. The ore is arsenopyrite, a double sulphide of arsenic and iron, associated with pyrite, and occurs in "veins" (lenses) in quartz-sericite schist, which is closely associated with a variable biotite gneiss, but the relations of the two rock types to each other, and of the gneiss to the ore bodies, are unknown.

PHOSPHATE.

Three forms of phosphatic material occur in the State, namely, (1) the marls of the Coastal Plain region, (2) pebble phosphate west of the Blue Ridge near Clifton Forge, and (3) dikes of nelsonite—a rock composed normally of a mixture of the minerals, ilmenite and apatite occurring in Nelson and Roanoke counties.

The shell and greensand marls of the Coastal Plain region frequently carry a small but variable percentage of phosphoric acid. These marls are not rich enough, however, in phosphoric acid to render them of commercial value as a source of phosphate.

West of the Blue Ridge, the occurrence of phosphatic nodules has been observed at the base of Devonian black shale, at Clifton Forge, but the extent of this material is yet unknown.

The nelsonite dikes in Nelson County are numerous and extend over a considerable area. Much variation is shown in the mineral composition of the rock composing the dikes. Normally, the rock is a granular mixture of the minerals white apatite and black ilmenite in variable proportion. Either mineral may predominate over the other in quantity. Near Rose's Mill, the ilmenite of some of the dikes is largely or entirely replaced by rutile giving at times a rock composed essentially of apatite and rutile with little or no ilmenite. In the vicinity of Lovingston, some of the dikes are composed principally of magnetite and biotite with a variable amount of apatite, while others are made up almost entirely of apatite. Chemical analyses of the nelsonite, collected from dikes over different parts of the area, show the calcium phosphate to range as high as 33 per cent.

The occurrence of the rock nelsonite in this county has been known for many years, and it has been prospected in a small way by open pits, cuts, and shafts at a number of places, chiefly near Roseland, Bryant, Rose's Mill, and Lovingston. The development work in the nelsonite dikes, near Rose's Mill, by the General Electric Company, was for the mineral rutile and not for the phosphate mineral apatite.

The dikes of nelsonite in Nelson County represent the largest concentration of phosphatic material yet known in the State. These deposits have been studied and mapped in detail by the Virginia Geological Survey, and a bulletin setting forth the results at considerable length will shortly be published. Phosphatic rock, not unlike the nelsonite of Nelson County, occurs about four miles east of Roanoke, where considerable prospecting was done about seven years ago.

GRAPHITE.

Graphite is rather widely distributed through the Piedmont region, occurring chiefly in the schists and gneisses, but as yet no actual production of the mineral has been reported. The occurrence of graphite has been noted in the following counties: Albemarle, Amelia, Buckingham, Charlotte, Loudoun, Louisa, Nelson, Orange, and Powhatan.

Probably the most encouraging occurrence of the mineral is in the northern part of Albemarle County, between Free Union and Boonsville, near Buck Mountain. The graphite occurs here in irregular vein-like masses in gneisses and syenites and their residual decay. It is of good quality, and blocks weighing several hundred pounds are easily extracted. The Naylor-Bruce Graphite Company acquired the property several years ago and made some developments on it, but closed down within a short time without any production.

RUTILE (Titanium).

The only locality in the Atlantic States where rutile has been mined in quantity is in the Tye River-Hat Creek area of Nelson County. The area is a large one, located in the foot-hills region of the Blue Ridge, and is distant about 7 miles northwest of the main line of the Southern Railway. A second area of commercial rutile was discovered recently in Goochland and Hanover counties about 20 miles west and northwest of Richmond.

Two distinct types of rutile are mined in the Nelson County area. In the first type, designated pegmatite rutile, the rutile occurs chiefly as disseminated grains of variable size in an igneous rock of very coarse- to medium-grained crystallization of feldspars and blue quartz with, in places, much hornblende. In the second type, designated nelsonite rutile, the rutile occurs in even-granular rocks, having dike-like characters, and composed normally of ilmenite and apatite. Near Rose's Mill, on Piney River, the ilmenite of the nelsonite is almost or entirely replaced at times by rutile, the rock ranging from an ilmenite-apatite mixture, in which little or no rutile is present, to a rutile-apatite mixture, containing but little ilmenite, with intermediate gradations in the ratio of ilmenite to rutile.

The American Rutile Company began mining the pegmatite rutile in 1901 from side-hill cuts along the east side of Tye River, a short distance below the entrance of Hat Creek, and, in 1902, a milling plant was built for concentrating the rutile. The rutile is very pure, of red to reddish brown color, and occurs chiefly as large and small grains, disseminated principally through the feldspar, but also in the blue quartz and the hornblende. The rutile is admixed in places with some ilmenite.

In 1907, the General Electrical Company began mining operations for rutile in the nelsonite dikes near Rose's Mill, about 7 miles northwest of Tye River post-office. After considerable prospecting had been done the rutile content of the dikes was found to be so irregular that work was abandoned in 1909. Hess reports that about 100 tons of rutile ore, carrying 50 per cent TiO_2, were shipped which yielded 35 tons of concentrates. The nelsonite dikes in this locality carry large percentages of rutile in places—the dikes being composed almost entirely of rutile and apatite, the former predominating, but have been found to grade both laterally and vertically into the normal ilmenite-apatite rock.

The recently discovered (1909) deposits of rutile in the eastern portion of the Virginia Piedmont province, are grouped about several centers in the same general area in Goochland and Hanover counties. These are the Nuckols farm between Peers and Johnson's Springs and the Brown farm at Waldelock, Goochland County, and the Bowe farm on the north side of the South Anna River, near Gouldin, Hanover County. Some prospecting for rutile has been done on each of these farms. The country rock is a gneiss of variant composition, penetrated by pegmatite dikes that closely conform to the structure of the enclosing gneiss. Both the enclosing gneiss and the pegmatites are usually deeply weathered. The pegmatite dikes show a somewhat marked foliated structure due probably to pressure effects chiefly. Rutile in very large quantity, ranging from fine grains to masses weighing several pounds, is scattered loose over the surface and in the soil. Masses of rutile weighing up to several hundreds pounds have been found on the Nuckols farm. More or less ilmenite is associated with the rutile and both occur as constituents of the pegmatite.

The rutile deposits of Virginia have been studied in detail by the Virginia Geological Survey, and a volume setting forth the results at considerable length will be published shortly.

According to Hess the total value of rutile concentrates produced in 1909 in the Nelson County area was estimated at $10,000. The production of rutile in Virginia during 1910 was 556 short tons, valued at $44,480.

LIST OF RUTILE (TITANIUM) OPERATORS

OPERATOR	OFFICE	MINE
American Rutile Co	Washington, D. C	Roseland
General Electric Co	Schenectady, N. Y	Rose's Mill
Myer, August	Richmond	Gouldin
Nuckols, A. C	Peers	Peers

MINERAL WATERS.

The mineral waters of Virginia are an important source of revenue in the State. Virginia has a very large number of spring resorts, and a great variety and abundance of well-known commercial waters. Virginia is second only to New York in the number of springs that are utilized commercially, and exceeds New York in the number of resorts.

All classes of mineral waters are found in the State, and some of these are among the most celebrated in the country. They are naturally divided into (1) those containing mineral salts in such proportion as to give them medicinal value, and (2) those approximately pure waters which are sold extensively for table or domestic use.

The production of mineral waters for 1909, exclusive of 83,254 gallons used in the manufacture of soft drinks, was 1,504,530 gallons, valued at $203,455, these figures representing a decrease from the roduction during the previous year, of 595,084 gallons in quantity, id $3,660 in value. It will be observed that, while there was such marked decrease in the quantity of mineral waters sold during 1909, ie value lacked only $3,660 of equalling that of the previous year. his is due to an increase in the average price per gallon of the water ıld, the average price in 1909 being 14 cents per gallon as against) cents per gallon in 1908.

The production of mineral waters in Virginia during 1910 nounted to 2,441,923 gallons, valued at $301,523. These figures, hich are exclusive of 48,252 gallons used in the manufacture of soft rinks, represent an increase over the 1909 production, of 937,393 allons in quantity, and $98,068 in value. The average price per allon of the water sold during 1910 was 12 cents.

The following table gives the production and value of mineral aters in Virginia from 1903 to 1910, inclusive.

roduction and Value of Mineral Waters in Virginia, 1903 to 1910.

Year	Springs reporting sales	Quantity sold Gallons	Value
03	41	2,561,502	$ 477,410
04	35	2,117,420	281,998
05	37	2,340,287	589,102
06	43	1,997,207	418,908
07	44	2,442,075	431,770
08	46	2,099,614[a]	207,115
09	49	1,504,530[a]	203,455
10	40	2,441,923[a]	301,523

[a] Amount used for soft drinks not included.

Of the $203,455 worth of mineral waters sold in Virginia during 909, $102,296 worth was sold for medicinal purposes and $101,159 'orth for table or domestic use. The total number of springs reported s producing in 1909 was 49, as against 46 in 1908. These were istributed among the following 26 counties: Albemarle, Alexandria, melia, Augusta, Bath, Botetourt, Campbell, Chesterfield, Culpeper, 'rederick, Henrico, Isle of Wight, Loudoun, Mecklenburg, Montomery, Norfolk, Nottoway, Prince Edward, Roanoke, Rockbridge, Rockingham, Surry, Sussex, Tazewell, Warwick, and Wythe. Several of the springs reported resorts, with total accommodations for 3,518 people, and eight reported bathing establishments.

Of the 1910 production of mineral waters, valued at $301,523, $153,633 worth was sold for medicinal purposes and $147,890 worth for table or domestic use. The total number of springs reported as producing in 1910 was 40. These were distributed among the following 23 counties: Alexandria, Amelia, Augusta, Bath, Botetourt, Campbell, Chesterfield, Culpeper, Franklin, Frederick, Isle of Wight, Loudoun, Mecklenburg, Montgomery, Nottoway, Prince Edward, Roanoke, Rockbridge, Rockingham, Surry, Sussex, Tazewell and Wythe. Several of the springs (11) reported resorts, with total accommodations for 2,105 guests.

Out of a total of 63 mineral springs credited to Virginia, 40 reported sales during the year 1910. The list of springs follows, with those producing in 1910 marked by an asterisk (*).

*Alexandria Well, Alexandria, Alexandria County.
*Alleghany Spring, Alleghany Springs, Montgomery County.
*Basic Spring, Basic City, Augusta County.
*Bath Alum Springs, McClung, Bath County.
*Bear Lithia Spring, near Elkton, Rockingham County.
*Beaufont Spring, Beaufont, Chesterfield County.
*Bellfont Lithia Spring, Manchester, Chesterfield County.
Berry Hill Mineral Spring, near Elkwood, Culpeper County.
*Blue Ridge Springs, Blue Ridge Springs, Botetourt County.
Brugh's Spring, near Nace, Botetourt County.
*Buckhead Lithia Springs, Buckhead Springs, Chesterfield County.
*Buffalo Lithia Springs, Buffalo Lithia Springs, Mecklenburg County.
*Burnett's Mineral Spring, Hudson Mill, Culpeper County.
*Campfield Lithia Spring, Temples Station, Chesterfield County.
*Carper Lithia Springs, Radford, Montgomery County.
Como Lithia Spring, East Richmond, Henrico County.
*Coppahaunk Lithia Springs, Waverly, Sussex County.
*Crockett Arsenic Lithia Spring, Crockett Springs, Montgomery County.

*Days Point Artesian Lithia Spring, Smithfield, Isle of Wight County.

Diamond Spring, Diamond Springs Station, Princess Anne County.

*Erup Mineral Spring, Glencarlyn, Alexandria County.

*Falling Springs, Falling Springs, Augusta County.

Farmville Lithia Springs, Farmville, Prince Edward County.

*Fonticello Lithia Spring, near Richmond, Chesterfield County.

*Harris Anti-Dyspeptic Spring, Burkeville, Nottoway County.

*Holly Lithia Springs, three miles east of Richmond, Chesterfield County.

Houston Chlorated Spring, Houston, Halifax County.

*Iron-Lithia Springs, Tiptop, Tazewell County.

*Jeffress Lithia Silica Spring, Jeffress, Mecklenburg County.

*Jordan White Sulphur Spring, Jordan Springs, Frederick County.

*Kayser Lithia Springs, Staunton, Augusta County.

*Lone Jack Spring, Lone Jack Station, Campbell County.

Magee's Chlorinated Lithia Spring, Clarksville, Mecklenburg County.

Manganese Sodium Iodide Spring, Hallsboro, Chesterfield County.

Massanetta Spring, Harrisonburg, Rockingham County.

*Mecklenburg Mineral Springs, Chase City, Mecklenburg County.

Mulberry Island Spring, Mulberry Island, Warwick County. (Name changed to Chloride Lithia Spring).

*Nye Lithia Springs, Wytheville, Wythe County.

O'Connell Lithia Spring, Stribling Springs, Augusta County.

Otterburn Lithia Spring, Amelia, Amelia County.

*Pæonian Springs, Pæonian Springs, Loudoun County.

Pantops Mountain Spring, 3 miles east of Charlottesville, Albemarle County.

Paradise Spring, Clifton Station, Fairfax County.

*Pickett Spring, Worsham, Prince Edward County.

Powhatan Spring, Ballston, Alexandria County.

Roanoke Lithia Spring, two and one-half miles west of Roanoke, Roanoke County.

*Rockbridge Alum Springs, Rockbridge Alum Springs, Rockbridge County.

*Rocky Mount Lithia-Magnesian Spring, Rocky Mount, Franklin County.
*Rubino Healing Springs, Rubino Healing Springs, Bath County.
*Seawright Magnesian Lithia Spring, Staunton, Augusta County.
Shenandoah Alum Springs, Shenandoah Alum Springs, Shenandoah County.
Smithfield Artesian Well, Smithfield, Isle of Wight County.
*Stribling Springs, near Mount Solon, Augusta County.
*Tripho-Lithia Spring, Claremont, Surry County.
Trois Fontaine Lithia Spring, South Hill, Mecklenburg County.
*Virginia Etna Springs, Vinton, Roanoke County.
Virginia Lithia Springs, Osceola, Chesterfield County.
*Virginia Magnesian Alkaline Spring, near Staunton, Augusta County.
Virginia White Rock Springs, Mount Solon, Augusta County.
*Wallawhatoola Springs, near Millboro Spring, Bath County.
Waterlick White Sulphur Spring, Waterlick, Warren County.
White Oak Mineral Spring, Norfolk, Norfolk County.
*Wyrick Mineral Spring, near Wytheville, Wythe County.

PRECIOUS STONES.

A variety of minerals of gem grade has been found in the crystalline rocks of the Piedmont province of Virginia. Some counties in this area, which seemingly offer good possibilities for the occurrence of gem material, have not yet been exploited for this purpose. The known counties which have either produced gem materials, or contain minerals which might be of desirable gem grade, are Amelia, Amherst, Bedford, Buckingham, Fairfax, Hanover, Nelson, and Spottsylvania. Of these, Amelia County is the best known and has produced the largest variety and quantity of gem material. This material has come from the mica mines opened in the pegmatite dikes near Amelia Courthouse.

Those minerals known to occur in Virginia which have been used, or are probably capable of being used, for gem material are quartz including several varieties, garnet including several varieties, allanite, kyanite, fluorite (chlorophane), feldspar including several species, microlite, apatite, beryl, turquoise, columbite, and helvite. Although these minerals occur in Virginia not all of them have been found to be of gem grade.

The value of the production of precious stones in Virginia for 1909 was $2,500. There was no reported production of precious stones in Virginia during the year 1910.

INDEX

Abrasive materials, 91-93.
  Corundum and emery, 91.
    Corundum, 91.
    Emery, 91.
  List of operators, 93.
  Millstones buhrstones), 91-92.
    Production of, 92.
Analyses, granite, 73.
Appalachian Mountains province, The, 11.
Arsenic, 111-112.
Asbestos, 97-98.
  List of operators, 98.
Ballast and concrete, 89.
Barytes, 102-104.
  List of operators, 104.
  Production of 104.
Brick clays, 53-55.
  Production of 54-55.
Brick, sand-lime, 70.
  List of operators, 70.
Cement, 63-67.
  lime and, 59-67.
  List of operators, 67.
Chert, 93.
Clay products, clays and, 50-59.
Clays and clay products, 50-59.
  Brick clays, 53-55.
    Production of, 54-55.
  Fire clays, 55.
  Kaolin, 56.
  List of operators, 56-59.
  Pottery clays, 56.
  Production of, 52, 53, 54-55.
Clays, brick, 53-55.
  Production of, 54-55.
  fire, 55.
  pottery, 56.
Coal, 38-45.
  List of operators, 44-45.
  Statistics of production of, 43-44.
Coastal Plain province, The, 9.
Cobalt, nickel and, 38.
Coke, 46-49.
  List of operators, 49.
  Statistics of manufacture of, 48, 49.
Concrete, ballast and, 89.
Copper, 31-35.
  Production of, 34-35.
Corundum, 91.
Corundum and emery, 91.
  Corundum, 91.
  Emery, 91.
Crushed stone, 88-90.
  Ballast and concrete, 89.
  Road materials, 89.
  Value of production of, 91.
Diatomaceous earth, 93-94.
Diversity of resources, 12-13.
Effects of weathering and erosion, 12.
Emery, 91.
Erosion, weathering and, effects of, 12.
Features, surface of, the State, 7-11.
Feldspar, 96.
  List of operators, 96.
Fire clays, 55.
Flux, furnace, 90-91.
  Production of, 91.
Furnace flux, 90-91.
  Production of, 91.
Gold and silver 27-30.
  Production of 30-31.
Granite, 72-76.
  Analyses of 73.
  List of operators, 76.
  Production of, 74-75.
Graphite, 113.
Gravel, sand and, 67-70.
  List of operators, 69-70.
  Production of, 68.
Gypsum, 105-106.
  List of operators, 106.
Introduction, 1-6.
  Tables, mineral production of Virginia, 2-6.
Iron ores and pig iron, 13-23.
  List of operators, 22-23.
  Statistics of production of, 20, 21, 22.
Kaolin, 56.
Lead and zinc, 35-37.
  Production of, 37.
Lime, 60-63.
  List of operators, 62-63.
  Production and value of, 61-62.
Lime and cement, 59-67.
  Lime, 60-63.
    List of operators, 62-63.
    Production and value of, 61-62.
  Cement, 63-67.
    List of operators, 67.
Limestone, 77-82.
  List of operators, 80-82.
  Value and production of, 79-80.
List of springs of mineral waters, 117-119.

- Manganese ores, 23–26.
  - List of operators, 26.
  - Production and value of, 26.
- Manufacture of coke, statistics of, 48.
- Map, physiographic provinces of Virginia, 8.
- Marble, 77.
- Marl, 107–108.
- Mica, 94–95.
  - List of operators, 95.
  - Production of, 95.
- Millstones (buhrstones), 91–93.
  - List of operators, 93.
  - Production of, 92.
- Mineral paints, 107.
  - List of operators, 107.
- Mineral production, tables of, 2–6.
- Mineral waters, 115–119.
  - List of springs of, 117–119.
  - Production and value of, 116.
- Nickel and cobalt, 38.
- Ores, iron, 13–23.
  - List of operators, 22–23.
  - Production of, 20, 21, 22.
- Ores, manganese, 23–26.
  - List of operators, 26.
  - Production and value of, 26.
- Phosphate, 112–113.
- Piedmont Plateau province, The, 10.
- Pig iron, production of, 22.
- Position, geographic, of Virginia, 7.
- Pottery clays, 56.
- Precious stones, 119.
- Preliminary generalities, 7–13.
  - Diversity of resources, 12–13.
  - Effects of weathering and erosion, 12.
  - Geographic position of Virginia, 7.
  - Surface features of the State, 7–11.
    - Appalachian Mountains province, 11.
    - Coastal Plain province, 9.
    - Piedmont Plateau province, 10.
- Production, barytes, 104.
  - brick clays, 54–55.
  - clays and clay products, 52, 53, 54, 55.
  - coal, 43–44.
  - coke, 48, 49.
  - copper, 34–35.
  - furnace flux, 91.
  - granite, 74–75.
  - gold and silver, 30–31.
  - iron ores, 20, 21, 22.
  - lead and zinc, 37.
  - lime, 61–62.
  - limestone, 79–80.
  - manganese ores, 26.
  - mica, 95.
  - millstones (buhrstones), 92.
  - mineral, of Virginia, 2–6.
  - mineral waters, 116–117.
  - pig iron, 22.
  - pyrite and pyrrhotite, 111.
  - sandstone, 84.
  - sand and gravel, 68.
  - slate, 88.
  - talc and soapstone, 101.
- Province, Coastal Plain, The, 9.
  - Appalachian Mountains, The, 11.
  - Piedmont Plateau, The, 10.
- Pyrite and pyrrhotite, 108–111.
  - List of operators, 111.
  - Production of, 111.
- Pyrrhotite, pyrite and, 108–111.
- Quartz, 93.
- Resources, diversity of, 12–13.
- Road materials, 89.
- Rutile (titanium), 113–115.
  - List of operators, 115.
- Salt, 106.
- Sand and gravel, 67–70.
  - List of operators, 69–70.
  - Production of, 68.
- Sand-lime brick, 70.
  - List of operators, 70.
- Sandstone, 82–84.
  - List of operators, 84.
  - Production of, 84.
- Silica, 93–94.
  - Chert, 93.
  - Diatomaceous earth, 93–94.
  - Quartz, 93.
- Silver, gold and, 27–30.
  - Production of, 30.
- Slate, 85–88.
  - List of operators, 88.
  - Production of, 88.
- Soapstone, talc and, 98–102.
  - List of operators, 102.
  - Production of, 101.
- Springs, mineral waters, list of, 117–119.
- Statistics of manufacture of coke, 48, 49.
- Stone, 71–91.
  - Crushed stone, 88–90.
    - Ballast and concrete, 89.
    - Road materials, 89.
    - Value of production of, 90.
  - Furnace flux, 90–91.
    - Production of, 91.
  - Granite, 72–76.
    - Analyses of, 73.
    - List of operators, 76.
    - Statistics of production, 74–75.
  - Limestone, 77–82.
    - List of operators, 80–82.
    - Value and production of, 79–80.
  - List of operators, 76, 80–82, 84, 88.

    Marble, 77.
    Sandstone, 82–84.
        List of operators, 84.
        Production of, 84.
    Slate, 85–88.
        List of operators, 88.
        Production of, 88.
    Value of production of, 71.
Surface features of the State, 7–11.
    Appalachian Mountains province, The, 11.
    Coastal Plain province, The, 9.
    Piedmont Plateau province, The, 10.
Tables, mineral production of Virginia, 2–6.
Talc and soapstone, 98–102.
    List of operators, 102.
    Production of, 101.
Tin, 37.
Titanium (rutile), 113–115.
    List of operators, 115.
    Value of production, 115.
Weathering and erosion, effects of, 12.
Zinc, lead and, 35–37.
    Production of, 37.